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THE

MILLER, MILLWRIGHT and MILLFURNISHER.

A PRACTICAL TREATISE,

ILLUSTRATED WITH FOUR HUNDRED ENGRAVINGS.

BY

ROBERT GRIMSHAW.

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PREFACE.

IN preparing this book for a large class of practical men, only slightly represented in technical literature, the author has aimed to give it a wider range than any work of the kind yet presented.

The material has been gathered from various sources. Many mills have been visited; interviews and extended correspondence have been held with practical and successful millers, millwrights and millfurnishers. The author has adapted and freely quoted from standard works, and from his own and other articles in the principal milling journals.

Much of the information given answers questions asked by those interested.

A large part of the work has been verified by competent specialists, whom the author heartily thanks.

Some of the subjects are mooted questions among the most skilled in the art; and in many such instances the claims of both sides are stated.

This book is intended not only for occasional reference, but for daily use. Many of the calculations and tests have been made specially for it.

It is not offered as infallible; but should be convenient and useful, and may serve as a basis for something better.

PHILADELPHIA, May 1, 1882.

PUBLISHER'S NOTICE.

THE Publisher, in offering this work to the milling public, wants to say that, recognizing the desirability of a practical and useful handbook in the arts of milling, millwrighting and millfurnishing, he engaged the services of an unbiased author, already well known in technical literature, with instructions to spare neither care nor expense in producing a correct and useful work. The task—which was a long one—is finished. The amount of matter as here presented is about three times greater than that in the largest prior work on the subject in the English language, and the illustrations are numerous and interesting. The style is clear and concise, and the work proves to be so comprehensive, that it has been thought advisable to print a much larger edition than was at first intended. The price has been made low so as to meet the demands of a large number of readers.

TABLE OF CONTENTS.

CHAPTER I.—MILL CONSTRUCTION.

PAGE.

Site—Plans—Cost of Excavation—Foundations—Frost—Walls (Stone)—Bricks—Mortar—Batter—Partitions—Chimneys—Beams—Floors—Doors and Windows—Sheathing—Plastering—Roofs—Leaders—Skylights—Ventilation—Lightning Rods, etc.—Paints—Fire-Proof Construction—Fires and their Causes—Artesian Wells—Tanks—Pumps—Hose—Hydraulic Ram—Chemical Extinguisher—Fixed Water Pipes—Steam Pipes—Heating—Lighting—Estimates, ... 9,

CHAPTER II.—MILL PLANS.

Roller and Burr Mills—New Process Burr Mill—Three-Run Mill—Two-Run Low Grinding Mill—Niagara Falls Mill—Burned Yaeger Mill—Deseronto Mill—Five-Run Burr Mill—Two-Run Burr Mill—Mill Office—Seven-Run Mill—Oliver Evans' Mill, ... 41

CHAPTER III.—MILLING DIAGRAMS.

Milling Diagrams, ... 71

CHAPTER IV.—POWER.

Waste of Power—Relative Cost of Steam and Water Power—Steam vs. Water—Power per Barrel of Flour, ... 75

CHAPTER V.—WATER-WHEELS WITH HORIZONTAL AXES.

Kinds of Wheels—Undershot—Breast—Overshot—Vertical vs. Turbine Wheels—The Largest Water-Wheels—Screw Flood Wheels, ... 77

CHAPTER VI.—TURBINES.

Theory—Vertical Wheels vs. Turbines—Useful Effect—The Victor Wheel—Ordering Wheels—High Falls—Steps—Clogging—Variations of Power—Water-Wheel Governors, . . . 80

CHAPTER VII.—SETTING WHEELS, ETC.

Setting Wheels—Areas of Races and Flumes—Building Flumes—Position of Flumes—Decked Penstock—Details of Raised Penstock—Low Falls—Open Penstock—Wooden Flume for Turbines under High Falls—Sizes of Gripes—Draft Tube—Racks—Flood Gates, . . . 99

CHAPTER VIII.—MEASURING WATER-POWER.

Falls—Theoretic Velocity and Discharge—Rules for Measurement by Weirs—Measurement by Floats—Stream Power—Work of Water-Wheels by Night and Day, ... 107

CHAPTER IX.—BOILERS.

Combustion—Fuels—Waste of Fuel—Material for Boilers—Effects of Heating—Testing Plate—Boiler Shapes—Laterally Fired Horizontal Boilers—Internal Firing—Tubular—Water Tubes—Elephant—Proportions—Draft Area of Tubes—Steam Room—Weakening Effects of Common Steam Domes—Flues and Tubes—Grate Bars—Setting—Smoke Consumers—Chimneys—Cowls—Steam Pipe—Dry Pipe—Safety Valves—Fusible Plugs—Pressure Gauges—Glass Water Gauge—Draft Regulator—Feed Pipe—Feed Pump—Injector—Steam Traps—Blow-Off Valve—Blowers—Heating and Filtering Feed-Water—Corrosion, External, Internal—Grooving—Incrustation—Character of Scale—Scale Preventatives—Management, ... 114

CHAPTER X.—THE STEAM ENGINE.

PAGE.

Steam — Mechanical Effect — Expansion — Throttling and Wire-Drawing — Back Pressure — Economy of High-Pressures—Condenser—Compression—Speed—Superheated Steam — Steam Jacket—Lagging—Governor — Gardner's Governor — Foundation—Steam Cylinders—Fly-Wheel—Stroke—Steam Chest—Area of Steam Ports—Piston Head—Piston Rod—Slides—Cross-Head—Connecting Rod—Crank Pin—Crank—Piston-Head Packing—Piston-Rod Packing—Care of Steam Engine—Pounding—Cylinder Lubrication—Indicator Diagrams and Expert Tests—Wheelock Engine—Computation of Horse-Power—Power and "Duty"—Cost of Putting in Steam Power—Cost of Fuel per Barrel of Flour, . . 157

CHAPTER XI.—TRANSMISSION—SHAFTING.

Shafting—Turned Shafting—Cold Rolled—Hot Finished—Hollow Shafts—Hangers—Bearings—Torsion—Couplings—Friction Clutch—To Line Up Shafting—Keys, ... 188

CHAPTER XII.—TRANSMISSION BY BELTING.

Belts, vs. Gears—Elements in Belt Transmission—Rubber Belts—Cotton—Rawhide—Leather—Duration—Requisites for Successful Belt Transmission—Tension—Sag—Tightening Pulleys—Lacing—Putting on Belts—Testing Strength and Grip—Laying Out—Carrying Power around a Corner by a Belt—Shifter, ... 199

CHAPTER XIII.—TRANSMISSION BY CHAINS.

Detachable Link Chain, ... 216

CHAPTER XIV.—TRANSMISSION BY GEARING.

Gearing—Loss of Power through Gears—Laying out Gear Teeth—Mortise Gearing—Laying out the Teeth of Mortise Wheels—Gear Wheels, ... 220

CHAPTER XV.—TRANSMISSION—PULLEYS.

Pulleys—Stepped Pulleys—Split Pulleys—Loose Pulleys—Idle Pulleys—Tractive Force—Lagging—Bevel and Mitre Friction Pulleys, ... 229

CHAPTER XVI.—ROPE TRANSMISSION.

Location of Power—Transmission of Power by Wire Ropes—Distance of Transmission—Driving Ropes—Sheaves for Wire Rope—Deflection of Ropes—Long Transmissions—Rope Connecting Rods, ... 237

CHAPTER XVII.—FRICTION AND LUBRICATION.

Friction—Function of Lubricant—Hot Bearings—Lubricants—Compounded Oils—Evaporation—Spontaneous Combustion—Purity—Action of Oils on Metals—Bearing Metals—Proportions of Bearings, ... 241

CHAPTER XVIII.—BACKLASH AND SIDE PULL.

Backlash—Coil Spring—Side Pull, ... 251

CHAPTER XIX.—GRAIN CLEANING.

Cleaning—Ending—Screens—Grading and Separation—Hungarian System of Cleaning—Cockle—Cockle Separation—Oat Separation—Grader and Dustless Separator—Smutter and Separator—Wheat Brush, ... 254

CHAPTER XX.—WHEAT DRYING AND HEATING.

Drying Wheat—Heating Wheats—Generators for Wheat Heaters in Water Mills—Thermometer Attachment for Wheat Heaters, ... 279

CHAPTER XXI.—GRANULATION AND GRINDING.

PAGE.

General Classification of Granulating and Grinding Devices—Disc Milling—Material of Discs—Burr Millstones—Oscillating Upper-Runner Horizontal Mill—Oscillating Under-Runner Horizontal Mill—Rigid Runner Horizontal Mills—Under-Runners—Vertical Mills—Iron Discs—Iron Cones—Methods of Driving Rolls—Cylindrical Rollers—Single Roller Working against a Curved Face—Materials of Rollers—Surface of Rollers—Grooved Chilled Iron Rolls—Smoothed Chilled Iron Rolls—Smooth Porcelain Biscuit Rolls, ... 283

CHAPTER XXII.—THE BURR-STONE.

Various Stones used for Grinding—Burr-stone Proper—La-Ferté-sous-Jouarre—Ordinary Millstones, ... 288

CHAPTER XXIII.—MOUNTING THE BURRS.

The Millstone—Building Up the Burrs—Size and Weight of Stones—Hurst Frames—Hoppers and Hopper Frames—Pinion Jack—Size of Pulleys—The Spindle—Different Forms of Cockheads—Setting the Bed—Tramming and Bridging—Iron Jackstick with Level—To Make a Tram—Bush—Tram-Pot—Stiff vs. Oscillating Drive—The Balanced Bail—Ordering a Bail—Drivers—The Dane Driver—Equilibrium—Balancing the Runner—Standing Balance—Running Balance—Centrifugal Force—Radius of Gyration—Putting in Running Balance—Point of Suspension—The Damsel Feeders—Automatic Stone Lift—Iron Burr Crane—Oiling Mill Spindles—Fitting a New Back—Cost of Building Up, ... 295

CHAPTER XXIV.—VARIOUS MILLSTONE DRESSES.

The Dress—Choice of Dress—Path of Material—Elements of Dress—Eye—Bosom—Face—Proportion of Land and Furrows—Duties of Furrows—Number of Quarters—Number of Furrows—Outline of Furrows—Circle Furrow—Hollandish Circle Dress—Improved Circle Dress—Logarithmic Spiral Dress—Angle of Furrow Crossing—Laying Out Circle Furrows—Direction of Furrows—Draft—Depth of Furrows—Furrow Section—Smoothness of Lands and Furrows—Old Quarter Dress—The Hughes Dress—Compromise Dress—Pennsylvania and New Jersey Dress—Old Style Equalizing Dress—New Style Equalizing Dress—Combination Dress—Dickson Dress—Southern Dress—Jones Dress—Bowman Dress—Arndt's Dress—Ward's Millstone Formula—Dressing for Regrinding—Other Dresses (for Old and New Process, for Middlings, for Corn, for Wheat, etc.) . . 319

CHAPTER XXV.—DRESSING THE BURRS.

First Dress—Picks—Tempering Mill Picks and Chisels—Position in Dressing—Paint Staff—Proof Staff—Staffing—Direction of Furrows—Draft Square—Furrow Strip—Redressing and Cracking—Cleaning Millstones—Mending Burr Faces—Pick Burr Dresser—Diamond Dressing—Benton Dresser—Hand Tools. 344

CHAPTER XXVI.—OPERATION OF THE BURRS,

Operation of Grinding—Diameter of Burrs—Table of Rim Speeds—Speed of Grinding—Dress and Quality of Stone—Trouble in Grinding—Quality of Burr Flour, ... 357

CHAPTER XXVII.—COOLING THE CHOP.

Millstone Ventilation—High-Pressure Aspiration, ... 361

CHAPTER XXVIII.—ATTRITION BY AIR-BLAST.

Attrition by Air-Blast, ... 366

CHAPTER XXIX.—IRON DISC MILLS.

Iron Disc Mills—Raymond Brothers' Mill—Jonathan Mills' Disc Machines, ... 367

CHAPTER XXX.—DETAILS OF DIFFERENT TYPES OF BURR MILLS.

Classificaiion of Mills—Usual Type of Mill.—Munson's Geared Under-Runner Mill—Munson's Portable Mill Spindle—Plantation Mills, ... 373

CHAPTER XXXI.—SYSTEMS AND PROCESSES.

Progress of Modern Milling—Hungarian Roller System—Why Hungarian System is Complicated—Details of 150-Barrel System—A 450-Barrel Roller Mill, ... 379

CHAPTER XXXII.—DETAILS OF ROLLERS AND FRAMES.

PAGE.

Roller Milling—Varieties of Roller Machines—Number of Rolls, Single and Three High—Jones' Single Roll Frame—Roll Pairs—Method of Driving—Length of Rolls—Diameter of Rolls—Surface of Rolls—Materials of Rolls—Soft-Iron Rolls—Forms of Corrugations—Stevens' Patents—Number of Corrugations—Twist of Corrugations—Feed and Pressure—Axial Pressure—Differential Speed—Speed Ratios—Capacity of Round Rib Rolls—Yield from Roller Milling—Amount of Break Flour—Color—Strength of Roller Flour—Power Required by Rolls—Labor Required with Rolls—Coolness with Roll Work—Rolls on Soft Wheats—Break Rolls for Soft Wheats—Break Rolls for Mixed Wheats—Rolls on Middlings—Bran Cleaning by Rolls—Gray's Roller Frame, ... 386

CHAPTER XXXIII.—MIDDLINGS MACHINES.

Middlings Machines—Middlings Milling by Burrs—Middlings Purifiers—Principle of the Purifier—Grading Middlings—Kinds of Middlings—Dusting Middlings—Keeping the Cloths Clean—Collecting and Grading Flour Dust—The G. T. Smith Purifier—Middlings Returns—Clothing—Number and Size of Purifiers—General Remarks on Purifiers—Grinding Unpurified Middlings—Bran Cleaning, ... 406

CHAPTER XXXIV.—BOLTING.

Bolting—Methods Employed—Bolting Cloths—Wire Cloths—Silk and Wire Bolting Cloths Compared—Mending Cloths—Cleaning Cloths—Putting on the Cloth—Sliding of the Chop—Speed of the Reels—Capacity of Reels—Care of the Bolts—Keeping the Cloth Clean—Reels—Bolting Chests—Speck Box—Improved Bolting Chest—Screw Bolt Feeder—Rules for Clothing—To Get out Middlings—Clothing for Single Reel—Three Reels—Six Reel Chest—Scalping—Dusting Reel—Custom Work—Altering Reels—Reels in the Hungarian System—Wire-Clothed Reels—The Centrifugal Machine—Wheat Meal Purification—Rebolting—Bolting for Custom Mills—Hints, ... 427

CHAPTER XXXV.—ELEVATING, SPOUTING AND CONVEYING.

Elevating—Link-Belt Elevators—Elevator Boot—Elevator Buckets—Air-blast Elevator—Storage Elevators—Hoppers and Sinks—Spouting—Endless-Chain Conveyors—Hollow-Shaft Conveyor—Pitch of Screw Conveyors—Discharge—Flexible Conveyor—Hoisting, . . . 453

CHAPTER XXXVI.—WEIGHING, TESTING, PACKING, BRANDING AND STORING.

Scales—Grain Meter—Inspection of Flour and Meal—Packing—Economic Flour Packer—Tallies—Adjustable Tally—Electric Tally—Brands, etc.—Storage, ... 470

CHAPTER XXXVII.—CHANGING AND ALTERING MILLS.

Changing Dress, etc., for New Process—Altering Mills, ... 482

CHAPTER XXXVIII.—MILLWRIGHTING.

Tools—How to Treat and Use a File—Marking Off—Timber Joints—Halving Together—Open Mortise and Tenon Joints—Regular Mortise and Tenon Joint—Blind Mortise and Tenon Joint—Dowel Joint—Various Methods of Setting the Bevels of a Hopper—Building an Overshot Wheel, ... 487

CHAPTER XXXIX.—COMPOSITION AND STRUCTURE OF THE WHEAT BERRY.

Composition and Structure of the Wheat Berry, ... 508

CHAPTER XL.—GRAIN DESTROYERS.

Vegetable Organisms—Weevils—Rats, ... 518

CHAPTER XLI.—MISCELLANEOUS.

Helps to the Miller—Duty—Ordering Machinery—Choice of Stone—Straightening Shafts—Cost and Depreciation of Machinery—Cost of Manufacture—Qualities of Wheat—Cost of Wheat Transportation—Prices of Wheat—Calculations—Problems and Solutions, . . 521

ALPHABETICAL SUBJECT INDEX

TO TEXT AND ILLUSTRATIONS.

[Illustrations are marked with an asterisk *.]

☞ Look for each Subject under the most Important Word in it.

PAGE.

ABSOLUTE Steam Pressure, . . . 163
Acid, Acetic, for Scaling Boilers, . 153
Acid, Carbonic, ... 114
" Impurities in Feed-Water, . . . 150
" Phosphoric, in Wheat, ... 511
" Sulphuric, in Wheat, ... 511
Action of Furrows,* 334
" of Oils on Metals, ... 248
" of Smooth Rolls,* 390
Actual Expansion Rates of Steam, . . 159
Adamson Joint for Boiler Flues, . . 126
Adhesion of Belts, ... 200
Adjustable Tally, ... 478
Advantages of Belt Transmission, . . 199
" of Wire Drawing, ... 161
Air, Analysis of, ... 114
Air-Blast Elevator,* 458, 459
Air Current in Burrs, ... 333, 361
" Pressure of, ... 157
" Required for Combustion of Various Fuels, ... 115
" Volume of, Unconsumed, . . . 114
" Seasoned Lumber, ... 19
" Weight of, ... 114
"Air Space" Boiler and Pipe Covering,* . 146
Albumen, ... 509
Albuminoids in Wheat, ... 510
Alignment of Shafting, ... 175
" Improper, ... 177
Allis & Co., Mill Plans, . . . 42, 47, 54, 58
" " Roller Frames,* . . 402, 403 404
Almond Oil, Action on Metals, . . . 249
Altering Mills, Cost of, ... 482
Altering Two-run Mill, ... 481
American Spring Wheat, Analysis, . . 511
Amidon (see Starch), ... 510
Analysis of Various Materials (see Index for each material).
"Anchor R" Blocks, ... 288
Andernach Stone, ... 288
Angle of Friction of Chop, ... 330
Angle of Furrow-crossing, . 323, 328, 330, 351
Animal Oil in Boilers, ... 150
" " in Cylinders, ... 175
" " upon Rubber Belts, . . . 200
Aniseed for Joints, ... 520
Anthracite Coal, ... 116, 125
" " Air Required for Combustion of, . . . 115
Anti-friction Metal, ... 193
Anti-Incrustator for Boilers, . . . 153
Arc of Contact of Belts, Influence of, 199, 202
Arches, above Flume, ... 13
" Brick, ... 30
" Flat, ... 20
" Terra-Cotta, for Floors, ... 20
Area of Boiler Tubes, ... 123
" of Burr Faces, ... 358
" of Chimneys, ... 137
" of Flume, ... 100
" of Head-Race, ... 100
" of Safety-Valve, Thurston's Rule, . 141
" of Steam Ports, ... 169
" of Tail-Race, ... 100

PAGE.

Arkell & Smiths' Paper Flour Sacks, . . 477
Arndt Dress, Under-Runner for Rye,* . 339
" " Under-Runner for Wheat,* . 340
Artesian Wells, ... 34
Asbestos Cement Boiler Covering, . . 146
" Lagging for Steam Engines, . . 165
" Packing, ... 171
Ash, Wood, ... 116
" in Fuel, ... 116
" in Wheat, ... 510
" of Wheat, Horsford's Analysis, . . 511
Ashes Causing Corrosion of Boilers, . . 150
" under Boilers, ... 153
Asphaltic Coal, ... 116
Atmospheric Pressure, ... 161
Attachments for Detachable Malleable Iron Link Chains,* . . . 218, 219
Attic, ... 22
Attrition Mill, ... 366
Augers, ... 487
Automatic Engines, Care and Management of, ... 174
" Stone Lift, ... 316
" Stop for Coil Spring, ... 252
" Stop for Governor, ... 166
Available Heat, ... 114
Average Total Steam Pressure, . . 159, 184
Axe, ... 487

BABBITT-METAL, ... 193
" for Bearings, . . . 249
Backing up Millstones, ... 318
Backlash, ... 202, 251
" Caused by Belt Elasticity, . . . 251
" from Gear Wheels, ... 251
" Motion Indicator to Detect, . . 251
" of Involute Gear Wheels, . . . 228
Back Pressure, ... 161, 162, 184
" from Feed-Water Heaters, . . . 149
Back-Water, Trouble from, ... 79
Bad Gearing, ... 75, 177
Bags. (See Sacks.)
Bail and Driver, the Dane,* 306
Bail, Ordering, ... 304
Balanced Bail, ... 304
Balance Rynd, Laying Off and Cutting the Holes in, ... 301
Balance, Running, ... 307, 308, 309
" Standing, ... 307, 308
" Wrong,* 310
Balancing Burrs,* 310, 311
" at Various Speeds. 309
" the Runner, ... 307
Balance Weight, Attaching a,* . . . 308
Balancing Device for Millstones.* . . 311
Baragwanath's Feed-Water Heater, . . 148
Barffing Shafting, ... 190
Bark in Turbines, ... 96
Barley, Screens for, ... 264
Barrels, Hoops for, ... 476
" Packing in, ... 476
" Paper, ... 476
" Tallies for, ... 479

PAGE.

Barrels, Wood-Pulp, ... 476
Barr's Table of Grate Areas, . . 132
Bars, Grate, ... 131
Batter of Walls, ... 17
Beams, Hodgkinson, ... 18
" Iron, ... 30
" Lagging of, ... 19
" Strength of, ... 18
Beater Machines, ... 283
Beard of Wheat,* 512
Bearings, ... 193, 202
" Brass, ... 249, 250
" Graphite for Hot, ... 244
" Iron, ... 249
" Length of, ... 250
" Main, Running Hot, ... 173
" Pressure on, ... 250
" Proportions of, ... 250
" Soft-Metal, ... 250
" Sulphur for Hot, ... 244
" Wear of, ... 245
" Upright Iron Journals for, . . . 192
Bearing Metal, Copper and Tin, . . . 249
Béchamp, ... 510
Bed-stone,* 375
Beech, ... 116, 117
Behrns and Brehmer Exhaust,* . 362, 363, 364
Belts, Adhesion of, ... 200
" Arc of Contact, Influence of, . 199, 202
" Bending of, ... 200
" Robert Briggs on Tractive Force of Leather, ... 233
" Broad, ... 200
" Buying Rubber, ... 200
" Carrying Power Around a Corner by,* 212
" Chemically Tanned, ... 200
" Clamps for, Walden's Tension Regulating,* 202, 203
" Cotton, ... 200
" Crossed, ... 199
" Cutting Holes in Floors for Straight Open,* 210
" Double, ... 201
" Driving Power of Single Leather . 201
" Driving Side, ... 202
" Dry Leather, ... 200
" Duration of, ... 200
" Effect of Animal Oil upon Rubber, . 200
" Elasticity of, Causing Backlash . 251
" for Roller Frames, ... 389
" for Wood-Working Machinery, . 202
" Friction of, ... 200, 203
" Glue for, ... 205
" Grain Side of Leather, . . . 202
" Half Twist,* 213
" Heating of, ... 203
" Horizontal, ... 199, 202
" Horse-power of, ... 201
" How to Put on, ... 206
" H. R. Towne upon Tractive Force of, 233
" Inclined, ... 199
" Influence of Contact Area, . . 199
" " " Position of, . . 199
" " " Speed of, . . 199
" " " Tension of, . . 199
" " and Width of, . . 199
" Lacing, ... 205
" Laying Out, ... 209
" Laying Out Holes for Quarter Turn,* 210
" Leather, ... 200
" Link,* 218
" Long, for Conveyors, ... 219
" Loss of Driving Power, . . . 201
" Material, Influence of, . . . 199
" Moist, ... 200
" Narrow, ... 200, 201
" New Leather, ... 202
" Oak Tanned, ... 200
" Oiling, ... 201
" Open, ... 199
" Plan and Elevation of Quarter-twist, 214
" Quarter-turn, ... 209
" Quarter-twist, . . . 211, 212, 213, 214
" Rawhide, ... 200
" Rubber, ... 200
" Sag of, ... 202
" Screeching of, ... 203
" Seams of, ... 206
" Semi-Tanned, ... 200

PAGE.

Belts, Shifter for, ... 215
" Single Leather, ... 199, 201
" Slack, ... 202
" Slipping of 202, 203
" Slipping of Rubber, . . 200, 204
" Speed of, ... 201
" Splicing, J. H. Cooper, . . . 205
" Stiffness of Single Leather, . . 201
" Strength of Single Leather, . . 201
" Stretching, ... 203, 204
" Succeeding Gears, ... 199
" Tensions of, ... 202, 205, 244
Belt, Tests of E. F. Bradford & Co.'s, . 209
Belts, Tests of Driving Power, . . . 202
" Tests of Grip, ... 207
Belt Tests, Leather, ... 209
" Tests of New York Belting and Packing Co.'s, ... 207
" Tests of Rubber, ... 209
Belts, Strength of, ... 207
" Thick and Thin, ... 199, 200
" Thickness of. 199
Belt Tightener for Richmond City Mill Works, ... 203
" Tightener, Improved,* . . . 202, 204
" Tightening, ... 177
Belts, Tractive Force of Leather, . . 233
" Transmission of, A. B. Couch on, . 199
" upon Flouring Machinery, . . 202
" *v.* Gears, ... 199
" Weight of Leather, . . . 200, 201
Belting, Length of Coils, ... 526
" System for 450-bbl. Roller Mill, . 385
" System for 150-bbl. Roller Mill. . 384
Bending of Belt, ... 200
Bent Furrows,* 324, 325
Benton Diamond Burr Dresser,* . . . 355
Best Journal Boxes for Shafting, . . 193
Beveled Friction Pulleys, ... 235
Bevels, Setting Hopper, ... 500
Bevel Shell Wheels,* 224
Bilgram's Method of Laying out Gears,* 220, 221
Birch, ... 116
Biscuit Rolls, ... 390
Bituminous Coal, ... 116, 125
" " Air Required for, . . 115
Blacklead as Lubricant, ... 245
" in Steam Cylinders, ... 176
Black Mortar, ... 17
Black Sea Wheat, ... 523
" " Analysis, ... 511
Black Weevil, ... 519
Blast Machines, ... 283
"Bleeding" of Boilers, ... 152
Blind Dowel Joint,* 499
" " with Mitre,* . . . 500
Blind, Single Mortise and Tenon,* . . 497
Blisters on Boilers, ... 155
Block Rubber, Hand,* 356
Blowers for Boilers, ... 147
Blowing off Boilers, ... 152, 155
Blow-off Valve, ... 145
Boarts for Burr Dressing, ... 354
Boiler, Arrangement of, ... 264
" and Pipe Covering with Air Space,* . 146
" Compound for, G. W. Lord's, . . 153
" Connections, ... 155
Boiler-Covering, ... 134, 145
" " Asbestos, ... 146
" " Chalmer's Spence, . . 146
" " Hair Felt, ... 146
" " Sectional Plaster, . . 146
Boiler, Explosions of, ... 128
" Foaming, ... 142
" Front, with McGinniss Smoke Consumer,* 137
" Heads, Thickness of, ... 123
" Plates, Burning of, ... 127
" " Effect of Heating on, . . 120
" " Mild Steel, ... 119
" " Strength of, ... 120
" " Testing of, . . . 119, 121
" Proportion, ... 125
" Required to Heat Buildings, . . 38
" Righter, ... 122
" Scale, ... 125
" Setting, ... 134
" " Hollow Walls for, . . 134
" " Lime Mortar in, . . 135
" " Proportions of, . . 137

PAGE.

Boiler Shapes, ... 121
" Shells, ... 121
" French, ... 125
" Tubes, Arrangement of, . 123
" Tubes, Draft Area, . . . 127
" Tubes, Fastening, ... 130
" Tubes, Lengths of, ... 123
" Tubular, ... 122
" Water, Condition of, . . . 154
Boilers, ... 114, 119
" Animal Oil in, ... 150
" Anti-Incrustation for, ... 153
" Area of Tubes, ... 123
" Acetic Acid for Scaling, . . 153
" Bleeding of, ... 152
" Blisters on, ... 155
" Blowing off, ... 155
" Blowing Down, ... 152
" Bridge Walls for, ... 135
" Cause and Remedy of Foaming, . 138
" Cane Juice Vinegar for Scaling, . 153
" Carbonate of Lime in, . . . 152
" Carbonate of Lime in Feed, . 153
" Carbonate of Magnesia in, . . 153
" Cast-Iron, ... 119
" Catechu for Scaling, . . . 153
" Chalk in, ... 152
" Circulation of, ... 127
" Cleaning, ... 127
" Common Salt in Feed-Water, . . 151
" Compound Tubular, ... 124
" Cooling Down, ... 152, 154
" Copper, ... 119
" Cornish, ... 122
" Corrugated Flues, ... 122
" Corrosion by Ashes, ... 150
" Corrosion by Galvanic Action, . . 150
" Corrosion by Sulphurous Coal, . . 150
" Corrosion by Soot and Ashes. . . 153
" Corrosion by Wood Fuel, . . . 150
" Corrosion of, ... 150
" Corrosion of, ... 125
" Croton Water for, ... 151
" Cylinder Oils in. 153
" Cylindrical 121
" Distillery Slops for Scaling, . . 153
" Dry Pipes for, ... 138
" Earth Oil for Scaling, ... 153
" Effect of Pure Water in, . . . 150
" Elephant, ... 122
" Expert Advice Concerning, . . 153
" External Corrosion of, . . . 150
" Fairbairn, ... 122
" Filling Up 155
" Fire Surface, ... 127
" Flues of, Adamson Joint for, . . 126
" Foaming, ... 125
" For Lime-Water Districts, . . . 148
" Foundations for Setting, . . . 134
" Foaming in, ... 155
" Foaming Caused by Sulphate of Lime in, ... 153
" Foaming in, ... 155
" Fruits for Scaling, ... 153
" Galloway, ... 122
" Glass Gauges for, ... 155
" Grate Surface, ... 123
" Grooving of, ... 126, 151
" Hanging of, ... 137
" Heating Surface, ... 123
" Hemlock Bark for Scaling . . . 153
" Horizontally and Vertically Fired, . 134
" Incrustation of, ... 151
" Inclination of, ... 137
" Internal Corrosion of, ... 150
" Internally Fired, ... 122
" Iron in Water, ... 152
" Joints of, ... 126
" Lugs for, ... 135
" Lake Superior Water for, . . . 150
" Lancashire, ... 122
" Leakage Caused by Corrosion, . . 150
" Leaks of, ... 155
" Life of, ... 153
" Lifting Water in, ... 126
" Logwood for, ... 153
" Low Water in, ... 154
" Management of, ... 153
" Marble in, ... 152
" Materials for, ... 119

PAGE.

Boilers, Molasses for Scaling, . . 153
" Necks of, ... 125
" Oak Bark for Scaling, . . . 153
" Petroleum for Scaling, . . . 153
" Potatoes for Scaling, ... 153
" Preventing Scale in, ... 152
" Priming, ... 126
" Rectangular, ... 121
" Removing Scale in, ... 153
" Replacing, ... 125
" Scale, Character of, . . . 152
" Scale in, ... 125
" Scaling, ... 125
" Seamless Steam, ... 131
" Sectional Covers, ... 146
" Setting, ... 122
" Slippery Elm for Scaling, . . 153
" Soda Ash for Scaling, ... 153
" Soft Deposits in, ... 152
" Soot Causing Corrosion of, . . 150
" Smut in, ... 153
" Starch for Scaling, ... 153
" Staying of, ... 128
" Steel, ... 119
" Sulphate of Lime in, . . 152, 153
" Sumach for Scaling, ... 153
" Sweeping, ... 126
" Tannic Acid for Scaling, . . . 153
" Tubes for, ... 122
" Tubulous, ... 124
" Two-Story, ... 122
" Vertical Fire Tube, ... 121
" Washing out, ... 152
" Water Tube. 124
" Wisconsin Water for, ... 150
" Wrought-Iron, ... 119
Boiling Point of Water, ... 157
Bolt Feeder. Screw,* 435
Bolting Chests,* 41, 433
Bolting Cloths, Silk (see special chapter,)* 427, 428
" Cloth, Wire*, F. G. Richardson's Acme, ... 429
Bolting for Spring Wheat, ... 437
Bolts, Parting up of, ... 361
Boot, Elevator, ... 454, 455
Boring Steam Cylinders, ... 168
Bosom, ... 321, 343
Basalt Burrs, ... 288
Boussingault, Analyses of Wheat, . . 505
Bowling Hoop, ... 126
Bowman Dress,* 339
Boxes, Plate, ... 193
" Setting Driver, ... 303
" Staffing, ... 171
Box Journal, ... 192
" Pivot, ... 192
" Self-Oiling Post Journal,* . . 193
Bracket for Conveyor Coupling, . . 195
Bradford, E. F., & Co , Belt Tests, . . 209
Brake for Fast-Running Machinery, . . 215
" Friction or Pony, ... 177
Bran, ... 512
" Danger from Fire by, . . . 32
" Dresser, Lawton & Arndt's, . . 426
" Duster, Plans for, ... 42
" Inspection of, ... 475
" Rolls, ... 395, 482
Brand, ... 518
Brands and Stencils, D. D. Childs, . . 481
Brass Bearings, ... 249, 250
Bread from Flour, Quantity of, . . . 525
Breadth of Gear Teeth, ... 226
Break, Reels for,* 443
Breast Wheels, Loss of Water-Power by, . 77
Brick for Arches, ... 30
" As a Fire-Proof Material, . . 29
" Hollow Walls of, ... 29
" Laying, per Day, Speed of, . . 16
Bricks, Number per Cubic Foot of Wall, . 17
" per Cubic Yard of Brick-work, . . 17
" Required for Walls, Number of, . 16
" Strength of, ... 16
" Test of, ... 16
" Walls of, ... 15
" Waste of, ... 17
" Weight of, ... 16
Bridge Walls for Boilers, . . 125, 135
Briggs, Robert, upon Tractive Force of Belts, ... 233

PAGE.

Bronze Phosphor, ... 193
Brown on Altering Mills, ... 483
" on Method of Getting Running Balance, ... 312
Brush, Champion Wheat,* 277
" Lubricant for, ... 245
" Ordinary,* 301
Bucket, Elevator, ... 456
" Shape of Water-Wheel, ... 77
Buck Mountain Coal, ... 116
Buckwheat, Screens for, ... 264
" To Remove Wild, ... 267
Burrs, Air Current in, ... 333
" Balancing,* 311
" Basalt, ... 288
" Blocks for, Size of, ... 288, 289
" Building up,* 290, 295
" Canary-colored, ... 288
" Cement for Joints, ... 29
" Cost of Building, ... 308
" Cost and Depreciation of, . . . 522
" Circumference of, ... 358
" Crane Irons for,* 316, 317
" Dark-colored, ... 288
" Diameter of, ... 358
" Drab, ... 288
" Driving Two Lines of, on One Shaft, 211
Burr Dresser, Diamond,* 354
" " Emery-Wheel, . . . 356
" Picks, ... 354
" Dressing, ... 341
" " Braits or Cadbons for, . 354
" Faces, Area of, ... 358
" " Cement for, ... 354
" " Cracking, ... 336
" " Mending, ... 354
" " Rings in, ... 293
" Flour, Quality of, ... 360
" Mill, Building for, ... 44
" " Three-Run, ... 42
" " Two-Run, ... 42
" " 450-bbl., ... 42
" " Fuel Required for Two-Run, . 42
" " New Process, ... 42
" " Noye & Sons' Two-Run, . . 67
" Eye of, ... 303
" Expansion of, ... 359
" for Corn, ... 288
" for Dry Grain, ... 288
" for Oats, ... 288
Burrs, Gradual Reduction on, . . . 380
" Granite, ... 288
" Gumming of, ... 257
" How to Order, ... 40
" Hughes' Rule for Draft in, . . . 333
" Jumping of, caused by Light Feed, . 96
" Lara, ... 288
" Lead-colored, ... 288
" Leveling, ... 297
" Method of Driving Two Lines of, from One Shaft,* 211
" Ordering, ... 294
" Plaster for Backs of, ... 318
" Porphyry, ... 288
" Quality of, ... 288
" Rim Speed of, ... 358
" Rubbing, ... 353
" Sandstone, ... 288
" Scrubbing, ... 257
Burr, Section of,* 303, 321
Burrs, Speed of, for Middlings and for Wheat, ... 482
" Trachyte, ... 288
" Washing, ... 353
" Weighting, ... 317
Burr Stones, ... 284, 288
" Cologne, ... 285
" Esopus, ... 285
" French, German, Georgia Gray, Hungarian, Peninsular, . . . 285
" Sardinian, Sarospataker Variegated, West Virginia and White, . 288
" New Stock, Yellow, various grades, . 289
" Manufacturing, ... 288
Building an Overshot Water-Wheel, . . 504
" Height of, ... 10
" for Burr Mill, ... 41
" for Roller Milling, ... 41
" up the Burrs, ... 290, 295
" Flumes, ... 100

PAGE.

Buildings, Boiler Required to Heat, . . 38
" Proper Time to Erect, . . . 14
" Proportions of, ... 10
" Settling of, ... 10
Bunt, ... 518
Burning of Boiler Plates, ... 127
Burning of Carbon, ... 114
Burning Sawdust, ... 132
Bush, ... 297
Kuehne & Bryants, ... 300
Buying Rubber Belts, ... 200
" Shafting, ... 190
" Steam Engines, ... 185

CAKING Coal, ... 116, 117
Calandria Granaria, ... 519
Calandra Pryzæ, ... 519
Callipering Shafting, ... 189
Calculations, ... 526, 537
Caldwell Conveyor,* 467
California Wheat, ... 511, 523
Carbo-hydrates, ... 510
Camber, ... 19
Cameron, Professor, ... 511
Camphor for Weevils, ... 520
Candles, ... 38
" Danger from, ... 33
Cane-Juice Vinegar for Scaling Boilers, . 153
Cannel Coal, ... 117
Capacity of Hydraulic Ram, ... 36
" of Stones, ... 322
" of Tanks, ... 34
Carbon, Burning of, ... 114
Carbons for Burr Dressing, ... 354
Carbonate of Lime in Boilers, ... 152
" " in Boiler Feed-Water, 147, 153
Carbonate of Magnesia in Boilers, . . 153
Carbonic Acid, ... 114
" Oxide, ... 114
Care of a Steam Engine, ... 173
Careful Firing, Economy of, ... 119
Carrying Power around a Corner by a Belt, 212
Cascade Mill Water-Wheel, ... 78
Case for Proof-Staff,* 349
Casein, ... 509
Cast Gears, ... 220
Cast-Iron Boilers, ... 119
" Disks 285
" Engine Cranks, ... 170
" Pillars, ... 14
" Pulleys, ... 202
" Radiators, ... 37
" Steam Cylinders, ... 168
Castor-Oil, Action on Metals, ... 249
" " for Leather Belt, . . . 204
" " as Lubricant, ... 245
Catechu for Scaling Boilers, ... 153
Causes of Fires, ... 31
Ceilings, ... 30
Cellar Walls, Mortar for, ... 17
Cellulose in Wheat, ... 510
Cement for Cold Weather Mason Work, . 15
" for Leather Pulley Covers, . . 235
" for Joints of Burrs, ... 290
" for Leather Belts, ... 205
" for Burr Faces, ... 354
Centre-Lift Tram-Pot,* 302
Centrifugal Reels,* . . . 445, 446, 447, 448
Centre-Vent Turbines, ... 81
Centrifugal Force, ... 307, 308, 309
" " in Millstones. . . . 332
" Governor, ... 165
Cerealine, ... 507
Chaff, to Take Out, ... 255
Chalk-Line, ... 490
Crossing of Furrows,* . . . . 328 to 332
Croton Water for Boilers, ... 151
Crown of Pulley, Influence of, . . . 199
" Roller Mill, Power Required, . . 76
Crushing Strength of Mortar, ... 17
Cubic Feet in Tanks, ... 34
Curbs, ... 296
" Cost and Depreciation of, . . . 522
Curved Dress, ... 324, 328, 329, 330
" Furrows, ... 324
Cushion in Steam Engine, ... 163
Cut Gears, ... 220
Cut-off of Slide-Valve Engine, ... 174
" of Steam Engines, . 158, 159, 161, 164

PAGE.

Cutting Holes in Floors for Straight Open Belts,* 210
Cylinder Lubricants, ... 148
" Lubrication, ... 175, 176
" Oils as Lubricants, ... 245
" " in boilers, ... 153
" Steam, Animal Oil in, ... 148
" Blacklead in, ... 176
" Boring, ... 168
" Cast-Iron, ... 168
" Graphite in, ... 176
" Horizontal 169
" Material for, ... 168
" Mineral Oils in, ... 148
" Oil Cups for, ... 176
" Plumbago in, ... 176
" Scale caused by Animal Oil in, . . 175
" Steel Bushes for Engine, ... 168
" Vertical, ... 169
" Work of Steam in, ... 184
Cylindrical Boilers, ... 121
" Rolls, ... 286
Chains, Attachments for Driving,*. . . 219
" Transmission by, ... 216
" D Tighteners for Detachable Link, . 219
" Sprockets for Detachable Link, . 219
" Detachable Link, ... 216
" Driving Elevators by, ... 217
" Ewart Driving, ... 216
" Malleable Iron Driving, ... 216
" Lubricating Sprockets, ... 219
Chalk in Boilers and Feed-Water, . 147, 152
Chalmers Spence Boiler Covering, . . . 146
" " Flue Cleaner, ... 154
Chamber, Combustion, ... 125
" Super-heating, ... 139
" Champion " Grader and Dustless Separator,* 274
Changing Mills (see Altering), ... 482
Character of Boiler Scales, ... 152
Charcoal, Air Required for Burning, . . 115
Cheapness of Power, ... 75
Cheat, to Remove, ... 256
Check Valve, ... 139
Chemically-Tanned Belts, ... 200
Chemical Extinguisher, ... 37
Cherry Coal. 117
Chests, Bolting, ... 41, 433
" Six-reel, ... 440
" Steam, ... 169
Chicago River Water for Boiler Feeding, . 150
" Rawhide Manufacturing Co. . . . 200
Chilled Cast-Iron Rolls, ... 390
Childs, S. D., Brands and Stencils, . . 481
Chisels, ... 487
Chimneys, ... 18, 138
" Area of, ... 137
" Diameter of, ... 137
Chloride of Lime for Rats, ... 520
Chlorine for Rats, ... 520
Choice of Dress, ... 319
" of Stone, ... 288—294, 521
(See also sub-heads).
Chokes, ... 177
Choking in the Eye, ... 315
" Chordal " upon Split Pulleys, . . . 230
Chop, Angle of Friction, ... 331
" Distribution by Furrows, . . . 331
" Heating, ... 322, 325, 361
" Cups for, ... 311
" Cooling the, ... 361
Christy Brothers & Co., Power Required, . 76
Chute Case, Outer, of Victor Wheel, . . 87
Chutes of Turbines, ... 81
Cigar Coat of Wheat Berry, ... 513
Circles, Areas, &c , ... 526
Circle Furrows, ... 324, 326
" " Laying Out, ... 332
" Quarter Dress,* 325
" Dress, Improved, ... 327
Circular Iron Proof Staff,* 349
Circulation of Boilers, ... 127
Circumference of Burrs, ... 358
Clawson Wheat Starch,* 516
Claviceps purpurea, ... 519
Cleaning Boilers, ... 127
" Flues, ... 153
" Grain, ... 253
" Millstones. 353
" Machinery, Where to Place, . 41, 254

PAGE.

Cleaning Machinery of Simpson & Gault Manufacturing Company, . . 256
" Machinery for 450-bbl. Mill, . . 41
" Screens for, ... 257
" System for Hominy, ... 265
" Wheat, Screens for, ... 256
" Winter Wheat, ... 256
Clearance in Steam Engines, ... 164
" Lack of, Causing Leakage, . . . 171
Clearing Curve of Gear Wheels, . . . 228
Clogging, ... 315
" of Middlings, ... 335
" of Turbines, ... 96
" of Millstone's Eye, ... 359
Cloth, Silk, Wire, Bolting, &c., . 427, 428, 429
" Brown's Rule, ... 436
" for Custom Reels, . 448, 449, 450, 451, 452
" for Custom Mill, ... 441
" for Custom Work, ... 439, 442
" for Dusting Reel, ... 442
" Four Reels, ... 449
" for Hard Spring Wheat, . . . 437
" for Hungarian System, ... 443
" for Merchant Work, ... 439
" for Michigan Wheat, ... 436
" for New Process, ... 441, 483
" for One-Run, ... 439, 450
" for Red Winter Wheat, ... 437
" Rules for, ... 435
Clothing Reels, Best Way to Cut Cloth, . 433
" " for Scalpers (see under sub-heads), . . . 442, 443
" " for Seven-Run Mill, . . 437
" " for Single Reel, . . . 441
" " Six-Reel Chest, . . . 441
" " for Soft Wheat, . . . 437
" " Three-Run Mill, . 441, 451, 483
" " to Get Out Middlings, . 439
" " to Take Out Dirt, . . 443
" " Two-Run Mill, . 441, 450, 484
" " for 20-foot Reel, . . . 441
" " for 24-foot Reel, . . . 441
" " two Reels, ... 449
Close Stones, Furrow Surface for, . . 322
Closure, Exhaust, ... 177
Clutches, Finger,* 195
" for Line Shafting,* . . . 195, 196
" Friction, ... 196, 197
Coal, ... 116
" Air Required for Anthracite and Bituminous, ... 115
" Anthracite, ... 115, 125
" Asphaltic, ... 116
" Bituminous, ... 125
" Buck Mountain, ... 116
" Cannel, ... 117
" Caking, ... 115, 117
" Cherry, ... 117
" Consumption, ... 177
" Consumption of Boilers, . . . 116
" Dust, Danger from Fire by, . . 32
" for 300-bbl. Mill, ... 187
" Gas, ... 117
" Harleigh Lehigh, ... 116
" Hydrogenous, ... 117
" Long Flaming, ... 115
" per Barrel of Flour, ... 187
" Scranton, ... 116
" Semi-Bituminous, ... 117
" Shaley, ... 117
Cocks, Gauge, ... 155
Cockhead, forms of, ... 297
" Height of, ... 308
Cockle, ... 266
" and Oat Separator,* 271
" Machines of Cockle Separator Manufacturing Company,* . 268, 269, 270
" Separator Screens, Indentations in,* 271
" Separator Manufacturing Co., . 268—270
" to Remove. 256
" Rolls for, ... 266
" Where Most Plentiful, ... 257
" Screens for, ... 257, 263, 264
" Machine, ... 41
" Machines, Capacity of, . . . 272
Coefficient of Friction, of Chop, . . . 331
" " of Rolls, . . . 391
Cogs, Hunting, ... 223
" Measurements for,* 222
" for Mortise Gears, ... 221

PAGE.

Coils of Belting, to Measure, . . . 526
Coil Spring, Hafner's Eureka, . . 251, 252
" " Automatic Stop for, . . 252
" " for Spindle, ... 251
Coils, Steam, ... 37
Coke, Air Required, ... 115
Cold-Rolled Shafting, ... 190
Cold Weather Work, Cement for, . . 15
Color of Flour, ... 360, 399, 475
Cologne Stones, ... 285
Columns, Shafting, ... 19
Colza Oil, Action on Metals, ... 248
Combination Dress, ... 320, 337
Combustion, ... 114
" Air Required for, ... 115
" Chamber, ... 125
" Gases of, ... 114
" Imperfect, ... 115, 118
" Losses of, ... 115
" Rate of, ... 116
" Slow, ... 32
" Spontaneous, ... 248
" Total Heat of, ... 115
Common Quarter Dress, Furrows Crossing Joints,* 341
" Salt in Boiler Feed-Water, . . . 151
"Common Sense" Millstone Balancing Device, ... 309
Compasses, ... 487
Complication of Hungarian System, . . 382
Composition and Structure of Wheat Berry, ... 508
Compounded Oils, ... 247
Compound Tubular Boiler, ... 124
Compression in Steam Engines, . . . 163
" Coupling, ... 193
Compromise Dress, ... 337
Computation of Horse-Power, . . . 182
Concave Breast. (See Single Roll.)
Concrete Filling for Floors, ... 20
Concave Breast with Single Roll, . . 387
Condition of Boiler Water, ... 154
" of Steam Engine, ... 177
" of Pulley, Influence of, . . . 199
Concave Furrows, ... 335
Condensation, ... 164, 177
Condenser, ... 163
Cones, Iron, for Grinding, ... 286
Cone Pulleys, Open Belts upon, . . . 229
Conical Rolls, ... 284
Connections for Boilers, ... 155
Connecting Rod (see Steam Engine), . . 170
" of Wire Rope,* 242
Connections, Smoke, ... 126
Consumer, McGinnis' Smoke, . . . 137
Construction, Fire-Proof, ... 29
" of Gear Teeth, ... 225
" of Mill, ... 9
Consumption of Coal, ... 177
" of Fuel, ... 131
" of Fuel per Hour, ... 42
" of Lubricants, ... 244
" of Coal by Boilers, ... 116
" of Power by Tenants, ... 177
Contact Area, Influence of Belts, . . 199
Convex Milling, ... 283
Conveyor, Caldwell's Spiral,* . . . 467
" Coupling, ... 194
" Bracket for, ... 195
" Double Chain,* 217
" Double Flight,* 466
" Flexible Spiral,* 468
" Flat,* 217
" Long Belts for, ... 29
" Flat, Single Link, ... 217
" Coupling, Bracket for, . . . 195
Cool Bolting, ... 361
" Grinding, ... 335, 387
Cooling-off Boilers, ... 152, 154
" the Chop, ... 361
Cooper, J. H., on Belt Splicing, . . . 205
Copper and Tin Bearing Metal, . . . 249
Copper Boilers, ... 119
Copperas for Rats, ... 520
Coquelicot (*Lychnis Githago*), . . . 266
Cord Wood, Weight of, ... 117
Cockhead, Forms of, ... 297
" Height of, ... 308
Corliss, Type of Engine Frame, . . . 175
" of Valve Gear for Steam Engines, 161

PAGE.

Corn, Burr for, ... 288
" Grinding, ... 343
" Dress for, ... 342
Corn Meal, Screens for, ... 262
Corn Mill,* 66
Corn, Screens for, ... 264
Corn Smut, ... 518
Cornish Boiler, ... 122
Correct Balancing, either Standing or Running,* 310
Corrosion of Boilers, ... 125, 150
" by Soot and Ashes, ... 154
" of Tubes, ... 131
Corrugated Shutters, ... 20
" Boiler Flues, ... 122
Corrugations of Rolls, ... 381, 395
" Depth of, ... 392
" Fineness of, ... 390
" Forms of, ... 391
" Number of, ... 395
" Round, ... 390
" Sharpness, ... 392
" Shallow, ... 394
Corundum Wheel Dresser, ... 337
Cost of Altering, ... 482
" of Building Burrs, ... 318
" and Depreciation of Machinery. . 522
" of Dressing Burrs, ... 318
" of Excavation, ... 11
" Cost of Facing and Furrowing, . . 318
" of Fifty Horse-Power Steam Engine. 185
" of Fuel, ... 75
" of Fuel per Barrel of Flour, . 185, 186
" of Hauling, ... 12, 15, 16
" of Manufacturing Flour, . . . 523
" of 100 Horse-Power Engine, . . 185
" of Putting in Steam-Power, . . 185
" of Wheat Transportation, . . . 525
Cotton Factories, Irregular Motion in, . 178
" Belts, ... 200
" Waste, Danger from Fire by, . . 32
Couch, A. B., on Belt Transmission, . . 197
Coupler, Conveyor, ... 194
" Spiral, ... 195
Coupling and Bearing for Conveyor,* . 194
" Compression, ... 193
" Gudgeon,* 196
" Flange, ... 194
" Plate, ... 195
Couplings for Shafting, ... 189, 193
Covering, Air Space for Pipes and Boilers, 146
" Forebay, ... 106
" for Boilers, ... 134, 145
" for Pipes, ... 145
" for Pulleys, ... 235
Cowls, ... 18, 137
Cracking Burr Faces, . . . 336, 344, 353, 381
" Picks, ... 345
Crane Irons for Burrs,* 316, 317
Crank of Engine, ... 170, 171
Crank-Pin, ... 170
Crawinkler Stone, ... 288
Cream-colored Burr, ... 288
Cresson, G. V., Turned Wrought-Iron Shafting, ... 188
Cribs for Flumes, ... 105
Cross-Head of Steam Engine, . . . 170
Crossed Belts, ... 199
Crossing Angle of Furrows, . . . 324, 328, 330

DAMP Bran, Danger from Fire by, . . 33
Damp Smut, Danger from Fire by, . . 33
Damsels,* 314, 315, 316
Dane Bail and Driver,* 305, 306
Danger from Fire through Elevator Heads, ... 31
" from Lights, ... 29
" of Overloading Safety Valve, . . 141
Dangerous Oils, ... 247
Dark-colored Burrs, ... 288
Day's Work Lathing, ... 22
" " of Plasterer, ... 22
Decked Penstock,* 101
Definition of Glutenous, ... 379
" of Processes, ... 380
Deflection of Wire Ropes, ... 239
Deflecting Plates for Boilers, . . . 138
Degermination, Ideal,* 372
Degerminator Mills,* 370

PAGE.

Delacroix, V. S., Composition and Structure of Wheat, ... 508
Depreciation of Machines, etc., ... 522
Depth of Corrugations, ... 392
" of Furrow for Middlings, ... 335
" of Furrow for Wheat, ... 335
Dessau, Black Diamonds, ... 354
Deseronto Mill, Noyes & Sons' Plan of,* 61, 63, 64
Detachable Link Chains, ... 216
Détacheurs,* 447, 448
Details of 150-bbl. Roller Mill, ... 383
" of Rollers and Frames, ... 386
Detroit Cylinder Lubricator, ... 176
Dextrine, ... 510
Diagonal Sheathing, ... 21
Diagrams, Indicator, ... 161, 177
" Milling, ... 71
Diameter of Burrs, ... 358
" of Chimneys, ... 137
" of Journals, ... 250
" of Rolls, ... 389
" of Shafting, ... 188
Diamond Dresser, Benton,* 355
" " Dessau, ... 354
" Dressing, ... 354
Diehl Wheat Starch,* 515
Dickson Dress,* 337, 338
Differential Block, Weston's,* 469
Differentially Speeded Saw-Tooth Rolls,* . 392
Dimensions of Turbines, ... 91
Direction of Furrows, ... 333, 352
Dirt, Reels for,* 443
" in Wheat, Quantity of, . . . 254, 256
Discharge of Water from Turbines or Water-Wheels, ... 82
" Velocity of Water. 107
Disc Milling, ... 283, 284
" Mills, Iron,* 286, 367
" of Raymond Brothers' Mill,* . . . 368
Discs, Cast-Iron, ... 285
" Ideal Action of,* 372
" Porcelain Block, ... 283
Disintegrators, ... 257
Distance between Gear Teeth, ... 225
" " Hangers, ... 191
" " Pulley Centres, . . 199
" " Grate Bars, . . . 132
" of Transmission by Wire Ropes, . 237
" between Shafts, ... 202
Distillery Slops for Scaling Boilers, . . 153
Distribution of Chop by Furrow, . . . 331
Dixon Crucible Co., Lubricant, . . . 245
Domes, Steam,* 129
Doors, Furnace, ... 137
" Iron, ... 20
" Trap, ... 23
Dormant Flour-Packing Scale,* 470
Double Belts, ... 201
" Chain Conveyor,* 217
" Flight Conveyor,* 466
" Turbine, ... 95
Dough from Flour, ... 476
Dowel Joints,* 497, 499, 500
Drab Burr-Stone, ... 288
Draft of Furrows, ... 325
" " Hughes' Rule, . . . 333
" Furrows with Equal, ... 327
" Regulator Preventing Smoke by, . 142
" Square Using,* 352, 353
" of Furnace, ... 115, 131
" Area of Boiler Tubes, ... 127
" Regulator, ... 142
" Tube for Turbines, ... 94, 106
Draught. (See Draft.)
Dress, ... 324
" Arndt, ... 340
" Bowman, ... 339
" Choice of, ... 319
" Circle Quarter,* 325
" Combination, ... 320, 327
" Compromise, ... 337
" for Corn Grinding, ... 342
" Curved, ... 328, 329, 330
" Dickson, ... 338
" Elements in, ... 320
" Evans,* 328
" First, ... 344
" Hollandish Circle, ... 327
" Improved Circle. 327
" Jones, ... 338

PAGE.

Dress, Logarithmic Spiral,* . . 326, 327, 328
" For Lower Runner for Rye, . . . 340
" for Middlings Grinding, ... 342
" New Circle,* 329
" for New Process Wheat Grinding, . 342
" New Style Equalizing, ... 337
" for Old Progress Wheat Grinding, . 342
" Old Style Equalizing, ... 337
" Pallet's 342
" Pennsylvania and New Jersey, . . 337
" Quarter, ... 328, 337
" Rye Grinding, ... 342
" Sickle 326, 337
" for Upper-Runners, ... 325, 330
" for Under-Runner for Wheat, . . 340
" Wiebe's,* 329
" Wrong Arrangement of Short Furrows for Quarter,* 328
" (Look also under sub-heads as Circle, Wheat, Rye, etc.)
Dresses, Test with Various, ... 335
" Various, ... 342
Dressers, Corundum Wheel, ... 337
" Emery-Wheel, ... 337
Dressing,* 350
" Burrs, ... 344
" Kaestner Burrs,* 377
" Cost of, ... 318
" Diamond, ... 354
" Position in, ... 347
" for Regrinding, ... 341
" Stone, ... 15
Driers, ... 28
Drift-wood, to Keep out of Flumes, . . 106
Drive, Stiff *v.* Oscillating, ... 303
Driver, ... 305
" Dane,* 305, 306
" Mortise for, ... 301
Driving Irons, Forms of,* 313
" Power of Pulleys, ... 235
" " of Single Leather Belts, . . 201
" Pulleys, Hafner's Equilibrium,* . 253
" Ropes, ... 239
" Side of Belt, ... 202
" Two Lines of Burrs from One Shaft, 211
Drop-Lift Step,* 434
Dry Grain, Burrs for, ... 288
" Leather Belts, ... 200
" Peat, ... 115
" Steam, ... 138
" " Economy of, ... 164
" Pipes for Boilers,* . . 128, 138, 139
" Wood, ... 115, 116
Drying and Heating Wheat, ... 279
Duplex Safety Valve, ... 141
Durant, W. N., Tallies, . . . 477, 478, 479
Duration of Belts, ... 200
" of Wire Ropes, ... 239
Dust Collector,* 413
" Effect of, in Mill, ... 24
" to Take Out, ... 255
Duty of Cornish Boiler, ... 122
" of Hands, ... 521
" of the Furrows, ... 322
Dynamometer, ... 177

EARTH Oil for Scaling Boilers, . . 153
Eccentric Straps, ... 173
Economic Flour Packer, ... 477
Economy of Dry Steam, ... 164
" of Heating Feed-Water, . . . 147
" of High Pressure in Steam Engines, 162
" of Steam Engines, ... 177, 185
" " Measure of, . . . 162
Edge Blocks, ... 289
Eels in Turbines, ... 96
Effects of Heating on Boiler Plates, . . 120
Electric Light, ... 38
" " Irregular Motion for, . . 178
" Tally,* 479
Elements in a Dress, ... 320
" in Belt Transmission, ... 199
Elephant Boiler, ... 122
Elevator, Air-Blast. 458, 459
" Boot,* 454, 455
" Bucket,* 456
" Driving Chains, ... 217
" Grain, End View,* 460
" Heads, Danger from Fire, . . . 31

PAGE.

Elevator of Niagara Falls Mill, . . . 50
" Pulley, Danger from Fire, . . 31
" Cost and Depreciation of, . . 523
" Detachable Chains for, . . . 219
" Speed of, ... 219
Elm, ... 116
Embryo, ... 513
Emery Wheel Dressers, . . . 337, 356
Ended Wheat, Reels for,* 265
Ending Reel, ... 257
" Stones, ... 257, 266
" " Flour from, ... 257
Endocarp, ... 513
Engine, Steam, Automatic and Slide-Valve Compared, ... 186
" Care of, ... 173
" Crank Pin of, ... 170
" Cranks, Cast-Iron, ... 170
" Friction of, ... 161
" Guides of, ... 169
" Horizontal, ... 175
" How to Order, ... 39
" Rating of, ... 177
" Regularity of, Speed, ... 165
" Running Away of, ... 167
" Running, Check upon, . . . 177
" Buying Steam, ... 185
" Care and Management of, . . . 174
" Economy of, ... 185
" Fast-Running, ... 164
" Guarantee of, ... 185
" Improved, Non-Condensing, . . 178
" Lubricating, ... 170
" Non-Condensing, ... 161
" Speed of, ... 164, 165, 175
" Size of, ... 175
" Cut-off, ... 164
" Stroke of, ... 169
" Throwing Over, ... 169
" Wheelock, ... 179
Enlargement of Mills, ... 11
Epernon Stone, ... 288
Epicarp, ... 513
Epicycloid Teeth, ... 221
Episperm, ... 513
Equal Draft for Furrows.* 327
Equally-Speeded Saw-Tooth Rolls,* . . 393
Equilibrium, ... 306
" Stable.* 307
" Unstabled,* 307
Ergot, ... 513, 519
Esopus Stone Quarry,* 292, 293
" Stones, ... 285, 288
Estimates, ... 39
Eureka Coil Spring,* 251, 252
Erysiphe Graminis, ... 519
Evans' Dress,* 328, 329
" Oliver, Model Mill of 1790,* . . 69
Evaporation of Mineral Oils, . . . 248
" of Water, ... 116
Ewart Driving Chain,* 216
Excavation, Cost of, ... 11
Excelsior Mill, Plans of,* . . . 54, 57
Exhaust, Behrns Brehmer,* . . . 363, 364
" Closure of, in Steam Engine, . . 177
" for Millstone, ... 335
" Steam for Feed-Water Heating, . 149
" " for Heating Boiler Feed-Water, 147
Expansion, Actual Rates of, . . . 159
" Joints for Steam Pipes, . . . 138
" of Burr, ... 359
" of Flues, ... 126
" of Iron Beams, ... 19
" Rates, ... 160, 184
" Regular, ... 159
" of Spindle, ... 359
" of Steam, ... 158
" Trap, ... 145
Experiments Concerning Boiler Covering at Newton's Tool Works, . . 146
Expert Advice Concerning Boilers, . . 153
" Tests, ... 177
Exports, Use of, ... 179
Explosion of Mills, ... 361
" of Reels, ... 33
" Precautions against, ... 33
" Windows to Lessen Effects of, . . 38
Export, Flour for, ... 279
External Corrosion of Boilers, . . . 150
Extinguisher, Chemical, ... 37

PAGE.

Extinguisher, Fire, ... 29, 37
Eye of Burr, ... 321, 303
" Clogging of, ... 359
Eyeless Pick,* 346
Eye Blocks, ... 295

FACE, ... 322
Facing and Furrowing, Cost of, . . 318
"Factor of Horse-Power," 183
Fairbairn Boiler, ... 122
Fall of Water, ... 107
" for Hydraulic Ram, ... 36
" for Overshot Wheel, ... 78
Fall River, Cost of Steam Equipment, . 75
Falls, Low, ... 102
" High, ... 103
Fan-Blast Attrition Mill,* 366
Fast Grinding, ... 359
" Running Machinery, Shifter for, . 215
" Running Engines, ... 164
Fastening Boiler Tubes, ... 130
" the Rynd and Driver Boxes, . . 302
Feather-Edge, ... 330
" Depth of, ... 335
Feed Pipe, ... 143
" Pump, Where to Put, ... 143
" Silent,* 314
" Water for Boilers, Economy of Heating, ... 147
" Water, Temperature of, . . . 143
" " Hard, ... 147
" " Fresh, ... 147
" " Filtering, ... 147, 148
" " Impurities in, . . . 147, 150
" " Heaters for Boilers,* 139, 149
" " " and Purifier, Steam Jacket,* 149
" Water Heater for Lime, . . . 153
" " " Back Pressure from, 149
" " " Baragwanath's, . . 148
" " Heating by Waste Steam, . 149
" " Table Showing Economy of, . 148
" " Nystrom on Percentage of Saving" 147
Feeding Various Materials, ... 315
Felt Lagging for Steam Engines, . . 165
Ferrules, ... 130
Fifty Horse-Power Steam Engine, Cost of, 185
Files, to Use, ... 488
Filling Boilers, ... 155
" Frame Walls, ... 21
Filtering Feed-Water, ... 147, 148
Fineness of Roller Corrugations, . . . 390
Finger Coupler,* 165
" Clutch,* 195
Fire-Box, Height of, ... 135
Fire-Brick Partitions, ... 30
Fire Extinguishers, ... 29, 37
" Extinguishment, Steam Pipes for, . 37
" Loss from in Yaeger Mill, . . . 30
Fire-Proof Material, Bricks Considered as, 29
" " Construction, ... 29
" " Floors, ... 20
Fire Surface, ... 127
" Temperature of, ... 117
Fires and their Causes, ... 31
Fire, Danger to Roofs by, ... 23
" Danger from, through Elevator Pulleys, ... 31
" from Damp Pan, Soft Coal, Candles, Smut, Spontaneous Combustion, etc., 33
" through Coal Dust, Flour, etc., . 32
" Precautions against, ... 33
" Months in which Mills Burn, . 31
" Prevention of, ... 29
" Protection from, ... 34
" Protection from, in the Washburn A Mill, ... 31
" Slicing of, ... 118
Firing, Economy of Careful, . . . 119
First Dress, ... 344
" Roller Mill, ... 382
Fitting a New Back, ... 317
Five-Run Mill, Sections of,* 65
Fixed Water-Pipes, ... 37
Flame, ... 114
Flange Coupling, ... 191
Flanks of Gear Teeth, ... 225
Flashing Point of Lubricants, . . . 247

PAGE.

Flat Arches, ... 20
" Belt, Pulleys for, ... 229
" Grinding, ... 280
Flaxseed, Screens for, ... 263, 264
Flesh Side of Leather Belts, ... 199
Flexible Spiral Conveyor,* 467, 468
Floats, Shape of, Water-Wheel, ... 77
" Measurement of Water-Power by, . 110
Flood-Gates, ... 106
Floor Beams, Support for, ... 19
" Plans, ... 19
Floors, ... 19
" for Storage, ... 20, 481
" Concrete Filling for, ... 20
" Fire-Proof, ... 20
" Mill, ... 11
Flour, Coal per Barrel of, ... 187
" Color of, ... 360, 399, 475
" Cost of Fuel per Barrel of, . . 186
" Danger from Fire by, ... 32
" Dough from, ... 476
" Mills, Dust causing Explosion of, . 361
" from Ending Stones, ... 257
" Feeding, ... 315
" Granular, ... 360
" Overheating, ... 359
Flour-Packer, Economic, ... 477
Flour-Packing Scale, Dormant, ... 470
Flour, Power Required per Barrel, . . 76
" Saving, ... 362
" Specky, ... 322, 336, 432, 436
" Storage of, ... 476
" Strength of, ... 476
" Strong, ... 517
" Testers,* 475
" Trier and Inspector, ... 475
" Yellow, ... 360
Flouring Machinery, Belts upon, . . . 202
Flow of Material, ... 11
" of Water in Turbines,* . . . 81, 82
Flues of Boilers, ... 126
" Expansion of, ... 126
Flue Cleaner, Chalmers-Spence,* . . 153, 154
Flutter Wheel, ... 77
Flumes for Turbines, ... 13, 92, 94
" Area of, ... 100
" Building, ... 100
" Cubes for, ... 105
" Position of, ... 100
" to Keep Driftwood out of, . . . 166
" Weight of Water in, ... 103
" with Victor Turbine, ... 92
Flume, under,* 104
Fly-Wheel, ... 168, 201
" upon Line Shafting, ... 194
Foaming in Boilers, ... 125, 142, 155
" Cause and Remedy of, ... 138
" caused by Scale, ... 148
" caused by Sulphate of Lime, . . 153
Force, Centrifugal,* 307
" " in Burrs, ... 332
" Tangential,* 307
Forced Draft, ... 115, 132
Forebay Covering, ... 106
Forms of Cockhead,* 297
" of Corrugations, ... 391
" of Driving Irons,* 313
Forest's Milling Diagram, ... 71
Foundations for Boiler Setting, . . . 134
" Mill, ... 12
Foundation of Steam Engine, ... 167
Four Hundred and Fifty Barrel Roller Mill, Belting System for, . . . 385
Four Hundred and Fifty Barrel Burr Mill, 42
Four Hundred and Fifty Barrel Mill, Building for, ... 41
Frame Buildings, Sheathing for, . . . 21
" for Engine, Corliss, ... 175
" Walls, Filling for, ... 21
Framing an Overshot, ... 506
Franklin Institute Tests of Steam Engine Governor, ... 167
French Windows, ... 38
" Boiler, ... 125
Fresh-Water Feed, ... 146
Freshets, ... 106
Freshly-Cut Wood, ... 116
Friction and Lubrication, ... 243
" Angle of the Chop, ... 330, 331
" Brake, ... 177

PAGE.

Friction Clutch, Hafner's,* . . . 196, 197
" Coefficient of Chop, ... 331
" Drive for Rolls, ... 286
" of Engine, ... 161
" of Journal, ... 243
" of Belt, ... 200, 203
" Pulleys, ... 235
" Tractive Force of, ... 234
" Rolling, ... 243
" Sliding, ... 243
" Solid, ... 243
" Water-Wheel Governor,* . . . 97
Frost, ... 14
Fruit Coats of Wheat, ... 513
Fruits for Scaling Boilers, ... 153
Fuel, Consumption of, ... 131
" " per hour, ... 42
" " in 250-Barrel Mill, . 187
" for 100-Barrel Mill, ... 186
" Required for Two-Run Burr Mill, . 42
" Cost of, ... 75
" per Barrel of Flour, Cost of, . . 186
" Loss from Unburned, ... 115
" Minnetonka Mill, Amount Consumed in, ... 187
" Moisture of, ... 117
" Qualities of, ... 117
" Waste of, ... 117
Fuels, ... 117
Function of Lubricants, ... 244
Furnace, ... 114
" Doors of, ... 137
" Height of, ... 125
" Hollow Walls for, ... 115
" Radiation from, ... 115
Furrows, Action of, ... 334
" Angle of Crossing,* . . . 328, 330–332
" Bent,* 324, 325
" Circle or Circular, ... 324, 326
" Concave, ... 335
" Curved, ... 324
" Crossing, Angle of, . . . 328, 330–332
" Direction of, ... 333, 352
" Draft of, ... 325, 333
" Duties of, ... 322
" Hollow, ... 235
" with Equal Draft,* 327
" Grain of Wheat in,* 322
" Gouge, ... 335
" and Lands, Smoothness of, . . 336
" Laying Out, ... 351
" Circle, Laying Out, . . . 332, 333
" Logarithmic, Laying Out, . . . 325
" Number of, ... 324
" Number of Parallel, ... 323
" Outline of, ... 324
" Radius of, ... 333
" Rectilinear, ... 324
" Reversed, ... 323
" Shearing Action of, ... 332
" Spiral, ... 325
" for Hard Wheat, ... 322
" for Middlings, Depth of, . . . 335
" for New Stock Burrs, ... 324
" for Porous Stone, ... 322, 324
" for Soft Wheat, ... 322
" Ventilating Action of, . . . 332
Furrow for Wheat, Depth of, ... 335
" Section, Proper,* 336
" " Wrong,* 336
" " for Low Grinding, . . . 335
" Strip, ... 352
" Surface for Close Stones, . . . 322
Fusible Plug, ... 141
Fuzz to Remove, ... 255
Furring of Gauge Cocks, ... 152

GALLOWAY Boiler, ... 122
" Gallons in Tanks, ... 34
Galvanic Action Causing Boiler Corrosion, . 150
Gardner's Steam Engine Governor,* . 166, 167
Garlic, ... 257
" How to Take Out, ... 41
Gas Coal, ... 117
Gases of Combustion, ... 114
" Illuminating, ... 38
Gate, Register for Turbine,* 88
Gates, Water, ... 34
Gauge Cocks, ... 155

PAGE.

Gauge Cocks, Furring of, ... 152
" " Glass Water, ... 141
Gauge Pressures, ... 155
Gauges, Pressure, ... 141
" Oscillation of Water in, . . . 122
" Velocity, ... 107
Geared Under-Runner Mill,* 374
Gearing, ... 220
" Bad, ... 75
" Badly Designed, ... 177
" for Water-Wheels, ... 86
" How to Order, ... 40
" Poole & Hunt's, ... 220
" Transmission by, ... 220
Gear Teeth, Breadth of, ... 226
" " Construction of, ... 225
" " Distance of, ... 225
" " Flanks of, ... 225
" " Laying Out, ... 220
" " Shoulders of, ... 225
" " Thickness of, ... 225
Gears, Cast, ... 220
" Cogs for Mortise, ... 221
" Cut, ... 220
" for Roller Frames, ... 389
" Involute,* 226
" Moulded Cast, ... 220
" Mortise, ... 221
" succeeded by Belts, ... 199
" Wooden, ... 221
Gear Wheels, Backlash from, ... 251
" " Backlash of Involute, . . 228
" " Bilgram's Method of Laying Out, ... 220
" " Calculations, ... 137
" " Cleaning Curve of, . . . 228
" " Laying out Involute, . . 227
" " Thickness of, ... 226
" " Velocity Ratio, ... 225
General Idea of Sheave for Wire Rope,* . 239
General Section of Mills' Machine,* . . 371
Generators for Steam Wheat Heaters, . 280
Geology of La Ferté, ... 291
Georgia Burr, ... 288
Germ, Analysis of, ... 510
German Burr, ... 288
" Wheat, Analysis, ... 511
Germ Rolls, ... 482
Glass Gauges for Boilers, ... 155
" Millstones, ... 284
" Water Gauge, ... 141
Gliadin, ... 509
Globes, Calculations of, ... 537
Glue for Belts, ... 205
Gluten, ... 507
" Percentage, ... 517
" Sacks, ... 513
Glutenous, Definition of, ... 379
Gouges, ... 488
Gouge Furrows, ... 335
Governor Steam Engine, Automatic Stop for, ... 166
Governor Centrifugal, ... 165
" for Water-Wheels, ... 96
" Gardner's Steam Engine,* . . 166, 167
" Steam Engine, ... 165
" Tests, ... 166
" Water-Wheel,* 97
Grader,* 274
Gradual Reduction Machine, Mills' Enlarged Section, ... 371
Gradual Reduction on Burrs, ... 330
Gradual Roller Reduction, Heaters, . . 281
Gradual Reduction. (Look under sub-heads Granulation, Rollers, Jonathan Mills, etc.,
Grain Cleaning, ... 253
" Destroyers, Chapter on, ... 518
" Elevator, End View,* 460
" of Wheat in Furrows,* 322
" Side of Leather Belt, ... 202
" to make Musty, Sweet, ... 254
" Weevil, ... 519
Granite Burrs, ... 288
Granular Flour, ... 360
Granulation (see sub-heads Grinding, &c.,* 357
Graphite as Lubricant, ... 245
" for Hot Bearings and Journals, . . 244
" for Wooden Bearings, ... 245
" in Steam Cylinders, ... 176

PAGE.

Grate Bars, ... 131
" " Distance of, ... 132
" " Shallow, ... 132
" " Length of, ... 125
" Surface, ... 123, 131, 132
" " Watt's Rule, ... 131
Gray Burr, ... 288
Gravel in Wheat, ... 254
Gray, W. D., Roller Frames,* . 402, 403, 404
Green Timber, ... 19
Grinding, ... 357
" Cool, ... 335, 387
" Coolness of, ... 387
" Corn, ... 343
" Fast, ... 359
" Flat, ... 380
" Furrow Section, for Low, . . . 335
" Hard Wheat, Dress for, . . . 342
" High, ... 380
" Middlings, ... 343
" Picks, ... 345
" Soft Wheat, ... 360
" Soft Wheat, Dress for, ... 342
" Speed of, ... 359
" Troubles in, ... 359
" Wheat, ... 295
Grit in Steam Chest caused by Scale, . . 148
Grip of Belts, Tests of, ... 207
Gross Power of a Water Fall, ... 111
Grooved Chilled-Iron Rolls, ... 287
Grooving of Boilers, ... 151, 126
Grubs, to Prevent, ... 529
Guarantee of Steam Engine, ... 185
Gudgeons, ... 505
Gudgeon, Coupling for, ... 196
" Plate, ... 196
" Wing, ... 196
Guides of Steam Engines, ... 169
Gum in Wheat, ... 510
Gumming of Burrs, ... 257
" of Lubricants, ... 245
Gyration, Radius of, ... 309

HAFNER, J. A., Equilibrium Driving Pulleys,* 253
Hafner's Eureka Coil Springs,* 252
Hafner Friction-Clutch, ... 196
Hairs of Wheat Berry,* 512
Hair-Felt Boiler Covering, ... 146
Hair for Plaster, ... 22
Half-Twist Belt,* 213
Halving Together,* 492
Hammers, ... 487, 488
Hancock Inspirator,* 143, 144
Hand-Block Rubber,* 356
Handles for Picks, ... 347
Hangers for Shafting, ... 191
" Distance between, ... 191
Hanging of Boilers, ... 137
Hard Spring Wheat, Rolls for, ... 395
" Maple Wood, ... 117
Hardening Steel, ... 345
Hard Wood, ... 116
Hardness of Wheats, ... 523
Hard Finish for Walls, ... 21
" Water for Feed, ... 147
" Wheat, ... 389
" Furrows for, ... 322
" Grinding, ... 279
Harris Safe Works, Magnets of, . . . 255
Harleigh Lehigh Coal, ... 116
Harrington & Oglesby, Grading Screens, . 264
Hauling, Cost of, ... 12, 15, 16
Heads of Boilers, Thickness, ... 123
Head Race, Area of, ... 100
Heat, Available, ... 114
" Latent, ... 157
" Sensible, ... 157
" Total of Combustion, ... 115
Heat Units, ... 115
Heating of Belt, ... 203
" of the Chop, . . . 322, 325, 343, 361
" of Eccentric Straps, ... 173
" Feed-Water,* 139, 147, 149
" Feed-Water by Waste Steam, . . . 149
" Surface of Boilers, ... 123
" Surface, Square Feet for Mills, . . . 37
Heaters (Wheat), Steam Generator for,* . 280
" Thermometer Attachment for,* . 281

PAGE

Heated Wheats, to Purify, ... 254
Heating, Value of Wood, ... 117
Heavy Side of Burr, Tendency of the,* . 310
Height of Building, ... 10
" of Cockhead, ... 308
" of Fire-box, ... 135
" of Furnace, ... 125
" of Roof, ... 22
Helps to the Miller, ... 521
Hemlock Bark for Scaling Boilers, . . 153
Herschel, C., Tests of Turbines by, . . 87
Hickory Wood, ... 116
Higgins, John C., Mill Picks, . . . 346
High Falls, ... 103
" " Wood Flume for,* . . . 104
High Heads for Turbines, ... 94
" Grinding, ... 380
" Water-Falls, ... 95
High Pressure, Aspiration, ... 362
" Pressures causing Leakage, . . 171
" " Economy of, in Steam Engines, ... 162
High Pressure Steam, ... 126
" " Steam Engine,* . . . .
" " " " Scale from . 162
" " Tables Showing Saving in Steam Engines by use of, 163
Hodgkinson Beam, ... 18
Hoisting Irons, ... 317
Holes in Walls, ... 19
Hollandish Circle Dress, ... 327
Hollow Birch Partitions, ... 17
" Brick Walls, ... 29
" Furnace Walls, ... 115
" Furrows, ... 335
" Shafting, ... 191
" Walls for Boiler Setting, . . . 134
Holyoke Flume, Tests in, ... 86
Hominy, Screens for, ... 264
" System of Clearing, ... 265
Honey Dew, ... 518
Hoops, Barrel, ... 476
" Bowling, ... 126
Hopper, Setting, Bevels,* 500
" of Gray's Roller Frame, . . . 104
" Scales,* 471
" Capacity of, ... 526
" Frames, ... 296
Horizontal Belts, ... 199, 202
" Cylinders, ... 169
" Cylinder Boilers, Laterally Fired, . 122
" Engine, ... 175
" Externally Fired, Boilers, . . . 134
Horse-Power of Belt, ... 201
" " Computation of, . . . 182
" " Factor of, ... 183
" " Mark's Formula for, . . 183
" " of Wire Ropes, ... 237
Horsford's, Professor, Analysis of Wheat Ash. 511
Hose, New York Belting and Packing Company's,* 35
Hot Bearings, ... 244
Hot-Rolled Shafting, ... 190
Hughes' Rule for Draft of Burrs, . . 333
Hulling, Stones for, ... 288
Hundred Horse-Power Steam Engine, Cost of, ... 185
Hundred and Fifty Barrel Mill, . . 383, 384
Hungarian Burrs, ... 288
" Roller System, ... 380
" System, Complication of, . . . 382
" Wheats, ... 382
Hunting Cog, ... 223
Hursts, ... 10, 211, 296
" Iron, ... 11
Hydrants, ... 34
Hydraulic Lime in Mortar, ... 17
" Ram, ... 35
" " Capacity of, ... 36
" " Fall for, ... 36
Hydrogen, ... 114
" Burning of, ... 115
Hydrogenous Coal, ... 117
Hyperbolic Logarithms, . . . 159, 160
Hyperboloid Rolls, ... 284

ICE in Water-Wheels, ... 78
Ideal Action of Discs for Splitting and Degermination,* 372

PAGE.

Idle Pulleys, ... 233
Illuminating Gas, ... 38
Imperfect Combustion, ... 115, 118
Impurities in Lubricants, ... 244
Inclination of Boilers, ... 137
Inclined Belts, ... 199
Incrustation of Boilers, ... 151
India-rubber Packing, ... 171
Indicator Diagrams, ... 161, 177
" " from Wheelock Engine at Cincinnati Exhibition,* . 178
Initial Steam Pressure Required, . . . 184
Injector, ... 143
Insect Powder, Persian, ... 520
Inspection of Bran, ... 475
" of Flour and Meal, ... 475
" of Wheat Cleaning Machinery, . . 11
Inspector and Flour Trier,* 475
Inward Flow Turbines, ... 81
Inspirator, Hancock, ... 143
Internal Corrosion of Boilers, . . . 150
Internally Fired Boilers, ... 122
Involute Gears, Approximate,* . . . 226
Irregular Motion, ... 178
" Power, ... 199
Iron Beams, ... 30
" Expansion of, ... 19
Iron Bearings, ... 249
" Burr Crane, ... 317
" Cones for Granulating, . . . 286
" Disc Mills,* 286, 367
" Doors, ... 20
" Hursts, ... 11
" in Wheat, ... 254
" Jackstick, with Level,* . . . 299
" Oxide in Wheat, ... 511
" Paint Staff,* 348
" Penstock,* 90
" Roof, ... 23
" Sashes, ... 38
" Water in Boilers, ... 152
" Windows, ... 20

JACK, Reel,* 434
" Jacket, Steam, ... 164
Jackstick, Iron, with Level,* . . 297, 299
Jersey Pine as Fuel, ... 117
Jet Condensers, Evils of, ... 150
Joints of Boilers, ... 126
" of Millstones, ... 290
Jonathan Mills' System, ... 383, 385
Jones' Dress,* 338
" Single Roller System, . . . 385
" Cost of Making Flour by, . . . 524
Jones, Ballard & Ballard Single Roller Mills, ... 387
Jonsdorfer Stone, ... 288
Journals, Diameter of, ... 250
" Boxes for, ... 192, 193
" Friction of, ... 243
" Stiffness of, ... 250
Jumping of Millstones 96
Jute Sacks for Flour, ... 476

KAESTNER Vertical Burr Mill,* . . 377
Katzenstein Piston-Rod Packing, . 171
Kerosene as a Lubricant, ... 245
Keys, ... 171
" for Shafting, ... 198
Key Seats in Shafting, ... 193
Kiln Dried Lumber, ... 19
Kiln Floors for Oats, ... 264
Killing Flour, ... 359
Kinds of Water-Wheels, ... 77
Kuehne & Bryant Bush,* 300

LACING Belts, ... 205, 206
Lacrosse Driver, ... 305
La Ferté, ... 284
" Geology of Manufacture of Millstones, ... 291
Lagging Felt for Steam Engines, . . 165
" of Pulleys, ... 201
" Asbestos for Steam Engines, . . 165
" Pulleys, ... 234
" Steam Cylinder, ... 165
" Wood for Steam Engines, . . . 165

PAGE.

Lake Superior Water for Boilers, . . 150
Lamps, ... 38
Lancashire Boiler, ... 122
Land and Furrow Surfaces, Proportion of, 322
Lap and Lead, ... 161
Lard Oil as Lubricant, ... 245
" " Action on Metals, ... 248
Large Wheat, Rules for,* 265
Latent Heat of Steam, ... 157
Lathing, Day's Work, ... 22
Laths for Plastering, ... 22
" Cover a Given Surface, ... 22
Laterally Fired Horizontal Cylinder Boilers, ... 122
Lava Burrs, ... 288
Lawton & Arndt's Bran Dresser,* . . 426
Laying off and Cutting the Holes in the Balance Rynd, ... 301
Laying out Belts, ... 209
" " Circle Furrows,*. . . 332, 333
" " Furrows,* 351
" " Gears, ... 220
" " Bilgram's Method,* . . 221
" " Fole's, for Quarter-turn Belts.* 210
" " Involute Gear Wheels, . . 227
" " Teeth of Mortise Teeth, . . 222
Lead and Lap, ... 161
Lead-colored Burrs, ... 288
Leaders, ... 24
" Number of,* 323
Leaks, ... 177
" of Boilers, ... 155
Leakage, caused by High Pressure, . . 171
" caused by Lack of Clearance, . . 171
" of Boilers, caused by Corrosion, . 150
Leaky Piston, ... 171
Leather Belts. 200
" " Castor-Oil for, . . . 204
" " Cement for, ... 205
" " Flesh Side, ... 199
" " Glue for, ... 205
" " New, ... 202
" " Tests, ... 209
" " To Prevent Rats Gnawing, . 204
" " Slipping of, ... 204
" Lagging for Pulleys, ... 235
Leaves in Turbines, ... 96
Left-Hand Valves, ... 34
Lengths of Bearings, ... 250
" of Boiler Tubes. 123
Length of Grate Bars, ... 125
" of Rolls. 389
Le Van on Steam Domes, ... 128
Level, ... 487
" Varying Water, ... 77
Leveling Bed-Plate of Steam Engine, . . 167
" Burrs. 297
Life of a Boiler, ... 154
Lifting of Water in Boilers, ... 126, 127
Light, Electric, ... 38
Light Feed causing Jumping of Burrs, . 96
" Grain, to Take Out, ... 255
Lighting Mills, ... 38
Lightning, Rods as a Protection Against, . 25
Lighter Screw,* 316
Light Materials, Reels for,* 444
Lights, Danger from, ... 29
Lignite, ... 115, 116
Lignumvitæ Stops, ... 95
Lime in Wheat, ... 511
" of Teil, ... 20
Line Shafting, Clutch for, ... 146
Limestone Feed-Water, ... 147, 153
Lime-Water Districts, Boilers for, . . 148
" Mortar in Boiler Setting, . . 135
Limy Districts, Tubular Boilers for, . . 148
Limy Carbonates in Feed-Water, . . 148
Line Shaft, Clutches on,* 197
Line Shafting Coupling, ... 194
" Journal Boxes for, ... 192
Lining up Shafting, ... 198
Link Belt Drive for Rolls, ... 286
" Belts, Ewart's,* 218
" " Attachments for,* . . . 219
Links, Method of Coupling,* . . . 216
Linseed Oil, Action on Metals, . . . 249
" " as Lubricant, ... 245
" " for Rubber Belts, . . . 204
Lining Wire Rope Sheaves,* 240
Load, Moving. 10

PAGE.

Logarithmic Spiral Dress,* . 325, 326, 327, 328
Logarithms, Hyperbolic, ... 159
Logwood for Scaling Boilers, . . . 153
Long Belts for Conveyors, ... 29
" Flaming Coal, ... 115
" Transmission, ... 239
Loose Pulleys, ... 233
Lord, G. W., Boiler Compound, . . . 153
Loss by Throttling and Wire-Drawing, . 161
" in Combustion, ... 115
" of Driving Power of Belts, . . 201
" of Heat by Scale, ... 148
" of Power through Gears, . . . 220
" Water-Power by Breast Wheel, . . 77
Lowell, Cost of Water-Power, . . . 75
Low Falls, ... 102
" Water in Boilers, ... 154
Lubricant, Blacklead as, ... 245
" Cylinder Oils as, ... 245
" Dixon Crucible Co.'s 245
" Graphite as a, ... 245
" Kerosene as a, ... 245
" Lard Oil as a, ... 245
" Linseed Oil as a, ... 245
" Neatsfoot Oil as a, ... 246
" Paraffine Oil as a, ... 246
" Plumbago as a, ... 245
" Spindle, ... 245
" Sperm Oil as a, ... 245, 246
" Tallow as a, ... 245, 246
" Value of. 244
Lubricating Steam Engines, ... 170
" Turbine Steps, ... 95
" Oil Cup, Sectional View,* . . . 176
" Sprockets and Chains, ... 219
Lubrication Cylinder. 175
" and Friction, ... 243
" Improper Waste of Power by, . . 177
Lubricants, Castor-Oil, ... 245
" Consumption of, ... 244
" Cylinder, ... 148
" Flashing Point of, ... 247
" for Brush Machines, ... 245
" for Separators, ... 245
" Function of. 244
" Gumming of, ... 245
" Impurities in. 244
" Purity of, ... 248
" for Smutters, ... 245
Lubricator for Cylinders, ... 176
" Detroit Cylinder, ... 176
Lugs for Boilers, ... 135
Lumber. Air-Seasoned, ... 19
" Kiln Dried, ... 19
Lychnis Githago, ... 266

MACHINERY, Brake for Fast Running, 215
" Cleaning for 450-bbl. Mill, 41
Machines, Cockle, ... 41, 42
Machinery, Shifter for Fast Running, . 215
" Vibrating Horizontal, ... 10
Magnets of Harris' Safe Works,* . . 255
" in Washburn B Mill, ... 254
Main Bearing Running Hot, ... 173
" Valve, Trunnions, &c.,* . . . 182
Malleable-Iron Driving Chain, . . . 216
Management of Boilers, Rules for, . . 154
Man-Holes. 125
Mansard Roofs. 30
Manufacture of Burr-Stone, ... 288
" of Flour, Cost of, ... 523
Marble in Boilers, ... 152
Marking off. 490
Marks, W. D., ... 284
" " Formula for Horse-power, . 183
Material, Flow of, ... 11
" for Boilers, ... 119
" of Rolls, ... 286, 390
" for Millstones, ... 288
" Supposed Path of,* . . . 320, 321
Maximum Velocity for Turbines, . . 81
McFeely's Diamond Dresser, ... 355
McGinniss' Smoke Consumer,* . . 136, 137
Meal, Feeding, ... 315
Mean Effective Pressure, . . . 162, 183
Measure of Economy of Steam Engines, . 162
Measurement by Weirs, ... 108
" of Water-power by Floats, . 107, 110
" for Cogs,* 222

PAGE.

Measuring Fall and Width of Stream,* . 111
Mesocarp, ... 513
Mechanical Effect of Steam, . . . 157
Mège Mouriès, ... 509, 513
Mending Burr Faces, ... 354
Magnesia in Wheat, ... 511
Metal, Anti-friction, ... 193
" Babbit, ... 240
" Bearing, ... 249
" Copper and Tin Bearing, . . . 249
" Packing,* 172
" Roofs, Protection for against Lightning, ... 26
" Rings for Engine Packing, . . . 171
Method of Coupling Links together,* . . 216
" of Driving Gray's Roller Frames,* . 403
" of Driving Rolls, ... 286, 388
" of Driving Two Lines of Burrs from One Shaft,* 211
" of Suspension,* 313
Michigan Wheat, to Treat, ... 257
" Winter Wheat, ... 523
Middlings-Burrs, Speed of, ... 482
Middlings, Clogging of, ... 335
" Danger from Fire by Spontaneous Combustion, ... 33
" Feeding, ... 315
" Grinding, ... 343
" Grinding Dress for, ... 342
" Making, ... 341, 359
" Percentage of Products in Roller, . 381
" Reels for,* 266
" Rye, ... 422
" Screens for, ... 262
" Stone for, ... 287
Mildew, ... 518, 519
Mild Steel Boiler Plates, ... 119
Mill Buildings, Construction of, . . . 9
" Floors, ... 11
" Foundations, ... 12
Mills, Explosion of, through Flour Dust, . 361
" Heating, ... 37
" Height of Washburn, ... 11
" Lighting, ... 38
" Oscillation of, ... 10
" Positions for Clearing Machines in, . 41
" Position for Scalping Reels in, . . 42
" Posts in, ... 14
" Sagging of, ... 19
" Vibrations of, ... 10
Mill-Dust, Effect of, ... 24
Milling Corn, ... 283
Milling Diagrams, Forrest, ... 7
" " Noyes & Sons, . . . 73
" " Novelty Iron Works,* . 73
Milling, Disc, ... 283, 284
" Plane, ... 283
Millstone. (See also Burr-Stone.)
Mill Spindles, Oiling, ... 317
Millwrighting Chapter, ... 487
Mill, Coal for 300-barrel, ... 187
" Hursts, ... 10
" Magnets in,* 255
" Offices, Nordyke & Marmon Plan of 70
" Oscillating Under-Runner, Horizontal, 285
" " Upper-Runner, " 285
" Smallest Roller that will Pay to Put up, ... 42
" Rigid Runner Horizontal, . . . 285
" Turbines of Niagara Falls, . . . 48
" Vertical, ... 286
" Plans, ... 41, 42, 71
" " Allis, ... 42, 47
" " Circumstances which Determine. 9
" 450-barrel, ... 41
" Niagara Falls,* 47, 48
" Section of,* 465
" Three-Run,* 43, 44
" Two-Run,* 42, 45
" Stones, What they are to be, . . 9
" Altering, ... 482
" Burr and Roller, ... 41
" Brown on Altering, ... 483
" Changing, ... 482
" Seneca Lake, ... 38
" Wood Burned in, ... 187
(See also sub-heads.)
Mills', Jonathan, Degerminator, *. . . 370
" " Reduction Disc, . . . 369, 372

PAGE.

Millstone Balancing Device,* . 309, 311
Millstones, Backing up, ... 318
" Cleaning, ... 353
" Success of, ... 319
" Exhaust for, ... 335
" Formula for, Ward's, ... 341
" Glass, ... 284
" Jumping of, ... 96
" Making, ... 293
" Materials of, ... 288
" Points of Suspension, ... 305
" Power Required by, ... 380
" Transparent, ... 321
" Ventilation of, ... 361
Mineral Impurities in Feed-Water, . 147
" Oils in Cylinders, ... 148
" Wool Lagging for Steam Engines, . 165
Minnetonka Mill, Fuel Consumed, . . 187
Miscellaneous Chapter, ... 521
Mitre Friction Pulleys, ... 235
Mitre, Solid,* 224
" Wheel, ... 224
Mixing Wheat, ... 525
Model Mill, Oliver Evans, Plan of, . 69
Modern Milling, Progress of, . . . 379
Moisture of Belts, ... 200
" of Fuel, ... 117
Molasses for Scaling Boilers, . . . 153
Moline, Water-power of, ... 75
Moore's Diamond Dresser Patent, . . 355
Mortar, ... 17, 21
" for Cellar Walls, ... 17
" for Outside Joints, ... 17
" Freezing of, ... 14
" How to Improve, ... 17
" Sand Requisite for, ... 17
" Mixed with Hydraulic Lime, . . 17
Mortise and Tenon,* 496
Mortise for Driver, ... 301
Mortise Teeth, Laying out, ... 222
Mortises, ... 505
Motion, Irregular, in Cotton Factories and Paper Mills, ... 178
" Irregular, of Electric Light, . . 178
" Unequal Valve, ... 177
" Indicator, to Detect Backlash, . . 251
Moulded Cast Gears, ... 220
Mounted Section of Burr,* 373
Mounting of Burrs, Chapter on, . . . 295
Months in which Mills Burn, . . . 31
Moving Load, ... 10
Mucedin, ... 509
Muddy Feed-Water, ... 147, 149
Mudsills, ... 99
Mule Pulleys, ... 215
Minden Stone, ... 288
Munson's Geared Under-Runner,* . . 374
Muskrats in Turbines, ... 96
Musty Grain, to Make Sweet, . . . 254
Mutterkorn, ... 519

NARROW Belts, ... 200, 201
Natural Drought, ... 131
Nature of Steam, ... 157
Neatsfoot Oil, Action on Metals, . . 246, 248
Necks of Boilers, ... 125
New Circle Dress,* 329
New Process Burr Mill, ... 42
" " Ten-Run Mill, ... 42
" " Thousand-Barrel Mill, . . 50
" " Wheat Grinding, Dress for, . 342
New Stock Burrs, ... 288, 289
" " Furrows for, ... 324
New Style Equalizing Dress, ... 337
Newton Machine Tool Works, Experiments at, Concerning Boiler and Pipe Coverings, ... 146
New York Belting and Packing Co.'s—
Belt Tests,* 173
Hose, ... 35
Piston-Rod Packing, ... 173
Water-Wheel, ... 79
Niagara Falls Mill,* 47, 48
" " Elevator of, . . . 50
" " Line of Stones,* . . 53
" " Packers,* 53
" " Sectional End View,* . 49
" " Turbines of, . . . 47
" " Wheel Pit, ... 53

PAGE.

Niagara Falls Mill, Wheels, &c.,* . . 52
"Nigger Shin" Plane, ... 487
Night Hands, ... 521
Nitrogen, ... 114
Nitrogenous Bodies, ... 509
Nolan, Jno. D., ... 512
Non-Caking Coal, ... 116
Non-Condensing Engines, ... 161
" " " Improved, . . . 178
Nordyke & Marmon's Plan of Mill Office,* . 70
Northwestern Roller Mill, Power Required, 76
Novelty Iron Works Milling Diagram,* . 71
Noye & Sons' Plan of Deseronto Mills, . 61
" " Two-Run Burr Mill, . . 67
" " Stevens Rolls, . . . 394—400
Number of Bricks, per Cubic Yard of Brick-work, ... 17
Number of Bricks Required for Walls, . 16, 17
" " Roll Corrugations, . . . 395
" " Furrows, ... 324
" " Quarters, ... 323
" " Short Furrows, ... 323

OAK BARK for Scaling Boilers, . . 153
Oak-Tanned Belts, ... 200
Oak-Wood, ... 116
Oat Smut, ... 518
Oats, Burr for, ... 288
" Kiln Floors for, ... 264
" Screens for, ... 264
" To take out, from Wheat, . . . 255
Office,* 70
Oils, Action on Metals of Almond, Castor, Linseed and Olive, ... 249
" Action of Colza, Lard, Neatsfoot and Sperm, ... 248
Oil in Wheat, ... 510
" Danger from Fire by, ... 31
" for Smutter, ... 247
Oiling Belts, ... 201
" Coupling Boxes of Shafting, . . 194
" Mill Spindles, ... 317
" Rubber Belts, ... 200
Oils, Compounded and Dangerous, . . 247
" Evaporation of, ... 248
" for Paints, ... 28
" Tests of, ... 38
Old Process Wheat Grinding, Dress for, . 342
Old Stock, ... 289
Old Style Equalizing Dress, ... 337
Oliver Evans' Model Mill of 1790,* . . 69
One Hundred and Fifty-Barrel Roller Mill, Belting System for, ... 384
One Hundred and Fifty-Barrel Roller Mill, Details of, ... 383
One Hundred-Barrel Mill, Fuel for, . . 186
" " " " Consumption of Wood for Fuel, . 187
Open Belts, ... 199
" " upon Cone Pulleys, . . . 229
" Double Mortise and Tenon,* . . 494
" Single Mortise and Tenon,* . . 493
" Mortise and Tenon at End of Rafter,* 498
" Penstock,* 103
" Stone, Furrows for, ... 322
Ordering Bails, ... 304
" Burrs, ... 40, 294
" Engine, ... 39
" Gearing, ... 40
" Machinery, ... 521
" Pulleys, Shafting and Spindles, . . 40
" Turbines, Directions for, . . . 39, 95
Oregon Wheat, ... 254, 525
Oscillating Drive, ... 303
Oscillating Under-Runner Horizontal Mill, . 285
" Upper-Runner Horizontal Mill, . . 285
Oscillation of Mills, ... 10
" of Water in Gauges, ... 122
Outline of Furrows, ... 324
Outside Joints, Mortar for, ... 17
Outward Flow Turbines, ... 81
Over-heating Flour, ... 359
Over-Pressure, ... 163
Overshot *v.* Turbines,* 83, 84, 85
Overshot Water-Wheel, ... 77
" " Building, . . . 504
" " Fall for, . . . 78
" " Large,* 78
" " Speed of, . . . 78

PAGE.

Oxide Carbonic, ... 114
Oxidation of Carbon, ... 114

Pacific Wheat, ... 523
Packers in Niagara Falls Mill,* . . 53
Packers, Simpson & Gault, ... 477
Packing, Asbestos, ... 171
" Bad, ... 177
" India-Rubber, ... 171
" Katzenstein Piston-Rod Packing, 171, 172
" Metal Rings for Engine, . . . 171
" New York Belting & Packing Company's, for Piston Rod, . . . 173
" Paper, ... 171
" Piston-Head, ... 171
" " Rod, ... 171
" Rubber Coil, ... 173
" Soapstone for, ... 171
" Tin Foil, ... 171
" Webbing for, ... 171
" Wheelock's, for Piston, . . . 182
" Wire-Cloth for Engine, . . . 171
" Flour in Barrels, ... 476
Painting, ... 351
Paints, ... 28
" Oils for, ... 28
Paint Staff, Iron, ... 348
" " Wooden, ... 348
Pair-Rolls, Running in Opposite Directions, 389
Pallet's Dress, ... 342
Paper Barrels, ... 476
" Flour Sacks, Arkell & Smiths', . . 477
" Mills, Irregular Motion in, . . . 178
" Packing, ... 171
" Tarred, ... 21
Paraffine Oil as Lubricant, ... 246
Parallel Flow Turbines, ... 81
" Furrows, Number of, ... 323
Part Gate, ... 86
Partitions, Fire-Brick, ... 30
" Hollow Brick, ... 17
Pasting up of Bolts, ... 361
Patent Handle. (See Picks.)
Patents, Stevens', ... 394, *et seq.*
Path of the Material in Under-Runners, . 321
" " " in Upper-Runners, . 320
Pearl Barley Machines, Screens for, . . 264
Peat, ... 115, 116
Penchet, Cost of Water-Power, at . . 75
Peninsula Stone, ... 285
Pennsylvania and New Jersey Dress, . 337
Penstock, ... 99
" Decked,* 101
" Iron,* 90
" Open,* 103
" Raised,* 100, 102
" Stone Piers for, ... 102
" Upright, ... 104
Percentage of Products in Roller Middlings, ... 381
Perforated Screens,* . . . . . 260—264
Performance of Steam, ... 159
" of Steam Engine, ... 177
Perg Stone, ... 288
Persian Insect Powder, ... 520
Petroleum for Scaling Oils, ... 153
Phosphor Bronze, ... 193
" " for Bearings, . . . 249
Phosphoric Acid in Wheat, ... 511
Pick Burr Dresser,* 354
Picking Rings,* 171, 182
Picks, ... 345
" for Cracking, ... 345
" Eyeless, ... 346
" Handles for, ... 347
" Higgins', ... 346
" in Patent Handle,* 347
" Restoring, ... 345
" Steel for, ... 345, 346
" to Grind, ... 346
" to Temper, ... 345
" with Eyes,* 346
Picking and Staffing, ... 344
Pillars, Cast-Iron, ... 14
" Settling of, ... 14
" Strength of Wooden, ... 19
Pine, ... 116
Pinion Jack, ... 296
Pipe Covering, ... 145

PAGE.

Pipe, Dry,* 128, 139
Pipes, Feed, ... 143
" Fixed Water, ... 37
" Steam, ... 138
Piston Head, ... 169, 182
" " Packing for. 171
" " Section of,* 182
Piston Rod. 169
" " Packing for, ... 171
Piston, Leaky, ... 171
Piston Packing, Wheelock, ... 182
Pit Wagon Scale,* 472
Pitch Circles, ... 225
Pitch of Roof, ... 24
Pivot Box for Shafting,* 192, 193
Plain Milling, ... 283
Plans of Elevators, . . . 459, 460, 461, 462
" of Excelsior Mill,* . . . . . 54—56
" for Cockle Machines, ... 42
" of Deseronto Mill, ... 61
" of Flour Mill, ... 19
" Floor. 19
Plans, Mill,* 41, 73
" " Circumstances which Determine, 9
" " What to be, ... 9
Plan of Mill Office, Nordyke & Marmon's,* 70
" of Oliver Evans' Model Mill, . . 69
Plans, Preliminary,* 72
Plan for Rolling Screens. 42
" of Seven-Run Burr Mill (Richmond Works), ... 67
" of Two-Run Mill,* 46
" of Yager Mill, ... 58
Plane Breast and Single Roll,* 387
Planes, ... 487
Plastering, ... 21
" Hair for, ... 22
" Laths for. 22
Plasterer, Day's Work of, ... 22
Plaster-of-Paris for Burr Backs, . . . 318
" " as a Fireproof Material, . 29
Plate Boxes,* 193
" Coupling,* 195
" Gudgeon,* 196
Plates, Deflecting, for Boilers, . . . 138
Plumbago as a Lubricant, ... 245
" in Steam Cylinders. 176
Point of Suspension of a Burr, . . . 305
" " Sergeant's Method of Getting, ... 313
Poole & Hunt, Gearing, ... 220
" " Pulleys, ... 229
Poplar, ... 116
Porcelain, Discs of, ... 283
" Rolls. 390
Porous Stone, Furrows for. 324
Porphyry Burrs, ... 288
Position in Burr Dressing, ... 347
Position of Belt, Influence of, . . . 199
" of Flumes. 100
Posts, Mill, ... 19
Potash in Wheat, ... 511
Potatoes for Scaling Boilers, ... 153
Pounding. 175
Pop Safety Valve, Scovell.* 140
Portable Mills, Spindle for,* 376
Power. 75
" Carrying Around a Corner by Belt. . 212
" Consumption of by Tenants. . . . 177
" to Drive Stones. 325
" How to Order Wheel for, ... 39
" Irregular, ... 199
" Loss of, through Gears, ... 220
" per Barrel of Flour, ... 76
" Required by Christy Brothers & Co., 76
" Required for Crowen Roller Mill, . 76
" " by Millstones. . . . 380
" " by Roller Mills, . . . 380
" " for Northwestern Roller Mill, ... 76
" " for Standard Mill, . . . 76
" " for Washburn B & C Mill, . 76
" Steam, ... 111
" Variations of, ... 96
" Waste of. 75
" Waste of, by Improper Lubrication, etc., 177
Precautions against Fire. 33
Preliminary Mill Plans,* 71, 72
Preparations for Raising Roofs, . . . 23
Pressure of Air, ... 157

PAGE.

Pressure of Steam, ... 159
" Absolute. 163
" Atmospheric, ... 161
" Average Total, ... 159, 184
" Back. 161, 184
" on Bearings. 250
" Gauges. 141, 155
" Initial, Required, ... 184
" Mean Effective, ... 162
" Over. 163
" Total Initial, ... 159
" Total, Final. 159
" "Under." 163
Preventing Scale in Boilers, ... 152
" Fire, ... 29
Prices of Turbines. 91
" of Wheat, Tables of. 527
Priming, ... 126
" caused by Scale, ... 148
Problems, ... 537
Progress of Modern Milling. 377
Processes, Definitions of. 380
" and Systems, ... 379
Prony Brake, ... 177
Proof Staff, Circular Iron* 349
" " Case for.* 349
Proportions of Bearings, ... 250
" of Building, ... 10
" of Boiler Setting, ... 137
Proportion of Land to Furrows, . . . 322
" of Boilers. 125
" of Mortar in Brick-Work. . . . 17
Protection from Fire. 34
" from Lightning. 25
Pulleys, ... 229
" Beveled Friction,* 235
" for Burrs. 296
" Calculations, ... 537
" Cement for Leather Covers. . . . 235
" Cast-Iron. 202
" Covering, ... 235
" Centres of, Distance between, . . 199
" Driving Power of, ... 235
" Diameter, Influence of, ... 199
" Flat Belts for. 229
" Friction,* 235
" How to Order, ... 40
" Idle. 233
" Influence of Revolutions per Minute. 199
Pulley, Influence of Crown, ... 199
" Influence Exerted by Condition of. . 199
Pulleys, Lagging, ... 234
" Leather, Lagging for, ... 235
" Loose. 233
" Mitre Friction, ... 235
" Mule,* 215
" Poole & Hunt's, Baltimore. . . . 229
" Rankin's Rule for Stepped. . . . 230
" Right Form of Beveled Friction,* . 235
" and Shafting, Set-Screws for. . . 199
" Size of. 201
" Slipping. 234
" Speed of, ... 201
" Split, ... 230
" Stepped, ... 229
" Tightening for Belts. . . . 202, 203
" Transmission by. 229
" Tractive Force of Friction. . . . 234
" Weight of, ... 229
" Wrong Form of Beveled Friction,* . 235
" Wrought-Iron Rim, ... 202
Punching Screens, ... 257
Pure Water, Effects of, in Boilers. . . 150
Purifiers, ... 41
" Air Current for. 418
" Capacity of, ... 417
" Centrifugal. 409
" Cleaning Cloths, ... 416
" Clothing for, ... 408, 416, 421
" on Coarse Middlings. . . . 410, 411
" Cost and Depreciation of, . . . 522
" for Custom Mills. 421
" Electrical. 409
" Function of. 409
" for Germ Middlings. 420
" G. T. Smith's Patents.* . . . 414, 415
" for High Grinding. 422
" Keeping Cloths Clean. 412
" for Merchant Mills. 421
" for New Process. 422

PAGE.

Purifiers, Ordering 424
" Original in Washburn Mill, . . . 416
" for Old Process, ... 422
" Prices of, ... 417
" Returning on, ... 418
" Principle of, ... 409
" for Spring Wheat, ... 342, 422
" (Look under Middlings Purifiers and Wheat Meal Purifiers.)
Purification, Trouble with, ... 359
Purity of Lubricants, ... 248
Putting on Belts, ... 206
Pyrethrum Roseum, ... 520
Pumps, ... 34
Pump, Rotary, ... 34
" Where to put Feed, ... 143
Pumping Hot Water, ... 143

QUALITIES of Burrs, ... 288
Qualities of Fuel, ... 117
Qualities of Wheat, ... 523
Quantity of Bread from Flour, ... 525
" of Dirt in Wheat, ... 254
Quarry, Esopus Stone,* 292, 293
Quarter Dress, ... 337
" " Wrong Arrangement of Short Furrows in,* . . 328
" " Straight,* 336
" " Sickle,* 336
" " Common,* 341
Quarters, Number of, ... 323
Quarter-twist Belt,* . 209, 211, 212, 213, 214

RACE, Tail, ... 94
Rack for Flumes, ... 106
Radiation from Furnace, ... 115
Radiators, Cast-iron, ... 37
Radius of Furrows, ... 333
" of Gyration, ... 309
Rafters,* 498
" for Sloped Roof, ... 22
Raised Penstock, ... 102
Ram, Hydraulic, ... 35
" Capacity of, ... 36
Rankine's Rule for Stepped Pulleys, . . 230
Rate of Combustion, ... 116
Rates, Expansion, ... 184
Rating of Engine, ... 177
Rats, ... 520
" to Prevent Gnawing Leather Belts, . 204
Rawhide Belts, ... 200
Reaction Water Wheels, ... 81
Rectangular Boilers, ... 121
Rectilinear Furrows, ... 324
Red Heart Hickory, ... 117
Red Oak, ... 117
Redressing, ... 352
Red Staff, ... 348
Red Staff (see Paint Staff).
Reduction Disc Mills',* 372
" Machine Mills',* 369
Red Winter Mediterranean Wheat, . . . 525
Reels for Ending,* 257
Reel Jack for,* 434
Reels, Cost and Depreciation of, . . . 522
" Explosion of, ... 33
" for Breaks,* 443
" for Coarse Dirt,* 443
" for Coarse Tailings,* 444
" for Ended Wheat,* 265
" for Fine Tailings, ... 444
" for Large Wheat,* 265
" for Light Material,* 444
" for Middlings,* 266
" for Small Semolina,* 266
" for Straw, Dirt, &c.,* 265
" for Tailings, ... 374
" for Wheat.* 443
Reflectors, ... 38
Register Gate,* 88
Regnault's Experiments Concerning Temperature of Steam, ... 158
Regrinding, Dressing for, ... 341
Regular Expansion, ... 159
Regular Single Mortise and Tenon,* . . 496
Regulator for Draft, ... 142
Regularity of Speed of Steam Engine, . 165
Relative Admission Periods of Steam, . . 159

PAGE.

Relative Cost of Water and Steam Power. 75
Release, ... 177
Removing Scale in Boilers, ... 153
Repairing Boilers, ... 125
Restoring Picks, ... 346
Return Tubular Boiler, ... 127
Reversed Furrows, ... 323
Revolutions per Minute of Pulley, Influence of, ... 199
Rhine Stone, ... 288
Rice's Steam Generator for Heaters,* . 280
Rice Weevil, ... 519
Richmond City Mill Works Burr Crane. . 317
" " " Belt Tightener, 203
" " " Plan of Seven-Run Mill, ... 67
Righter Boiler, ... 122
Rigid Runner Horizontal Mill, ... 288
Rim Speed of Burrs, ... 358
Rings in Burr Faces, ... 295
Rings, Packing,* 171, 182
Rittenhausen, Analysis of Gluten, . . 509
Rod, Piston, ... 169
Roll Pairs, ... 388
" Pair, Running in Opposite Directions,* 389
Roller and Burr Mills, ... 41
Roller Frames, Belts for, ... 389
" " Details of, ... 386
" " Gears for, ... 389
" Frame, Gray's,* 402
" Machines, Varieties of, ... 386
" Milling, Percentage of Products in, . 381
" Mill, First, ... 382
" " Shafting for 450-bbl., . . . 42
" " Smallest that will Pay to Put up, 42
" Mills, Power Required by, . . . 380
" Milling, Building for, ... 41
Rollers, ... 482
Roller, System, Hungarian, ... 380
Rolling Friction, ... 243
" Screens, ... 257
" " Plan for, ... 42
Rolls, Biscuit, ... 390
" Bran, ... 482
" Chilled Cast-Iron, ... 390
" Coefficient of, Friction from, . . 391
" Conical, ... 284
" Cylindrical, ... 286
" Diameter of, ... 389
" Differentially Speeded Saw Tooth,* . 392
" Equally Speeded Saw Tooth,* . . 393
" for Bran, ... 395
" for Cockle, ... 266
" for Hard Spring Wheat, . . . 395
" for Soft Winter Wheat, . . . 395
" Friction, Drive for, ... 286
" Germ, ... 482
" Grooved Chilled-Iron, ... 287
" Hyperboloid, ... 284
" Length of, ... 389
" Link Belt, Drive for, ... 286
" Materials of, ... 286, 390
" Methods of Driving, . . . 386, 388
" on Soft Wheats, ... 394
" Porcelain, ... 390
" Saw Tooth, ... 392
" Scotch, ... 394
" Single, ... 386
" " Acting against Curved Face, . 286
" " Cost of Making Flour by, . 523
" Smooth, ... 482
" " Chilled-Iron, ... 287
" " Porcelain Biscuit, ... 287
" Soft-Iron, ... 390
" Stevens', ... 389
" Surface of, ... 286, 390
" Three High, ... 286, 386
" Toothed,* 394
" Whiteness of Flour from, . . . 391
Roofs, ... 22
" Danger to, by Fire, ... 23
" Height of, ... 22
" for Snow, ... 23
" Iron, ... 23
" Mansard, ... 30
" Pitch of, ... 24
" Preparations for Raising, . . . 23
" Protection against Lightning by Metal, ... 26
" Sheathing, ... 23

PAGE.
Roofs, Sloped, ... 22
" Tin, ... 23
Room, Steam, ... 127
Rope, Deflection of Wire, ... 239
" Distance of Transmission by Wire, 237
" Driving, ... 239
" Duration of Wire, ... 239
" Horse-Power of, ... 237
" Sheave for, ... 239
" Tension of Wire, ... 237
" Transmission, ... 237
" Wire, ... 199
Rotary Pumps, ... 34
Round Corrugations, ... 390
Rubber Belt, ... 200
" Belts, Linseed Oil for, ... 204
" " Slipping of, ... 204
" " Tests of, ... 209
" Coil Packing, ... 173
" Stamps, Holderness & Co., . . 481
Rubbing Burrs, ... 353
Rules for Management of Steam Boilers, . 154
Running Away of Engine, ... 167
Running Balance, ... 307—309
" " Brown's Method of Getting, ... 312
Running, Check on Engine, ... 177
Russian Wheat, ... 511, 525
Rust, ... 518
Rye Grinding, Dress for Lower Runner for, ... 339, 340
Rye Grinding, Dress for, ... 342
" " Middlings, ... 422
" " Stone for, ... 288, 289
" Screens for, ... 264
" When to Clean, ... 256

SACKS, ... 476
Sacks, Jute, ... 476
Sacks, Paper, ... 477
" Seamless Cotton, ... 476
Saws, ... 487
Safety Valve, ... 139, 155
" " Area of, ... 141
" " Danger of Overloading, . . 141
" " Duplex, ... 141
" " Scovell Pop, ... 140
Sagging of Beams, ... 19
" of Mill, ... 19
" of Belts, ... 202
Saint Blasieu Turbine, ... 95
Saltillo Turbine, ... 95
Salt in Feed-Water, ... 147
Sand in Feed-Water, ... 148
" Requiste for Mortar, ... 17
Sandstone Burrs, ... 288
Sardinian Burr, ... 288
Sarospataker Burr, ... 288
Sashes, Iron, ... 38
Saving by Using Steam Expansively, . . 161
Sawdust, Burning, ... 132
" in Turbines, ... 96
Saw-Tooth Rolls, ... 392
" " Equally Speeded, ... 393
"S" Burr Blocks, ... 289
Scale, in Boilers, ... 125
" caused by Animal Oil in Cylinders. 175
" causing Grit in Steam Chest, . . 148
" Foaming caused by, ... 148
" Loss of Heat by, ... 148
" Priming caused by, ... 148
" Stoppages caused by, ... 148
" Dormant,* 470
" for High Pressure Steam Engine,* . 162
Scales, Hopper,* 471
Scaling Boilers, ... 125, 151
Scalping Reels, Where to go, ... 42
Scarf-Spliced Shaft,* 194, 195
Schleider, ... 510
Schmidt on Furrow-Crossing, ... 331
Scovell Pop Safety Valve,* 140
Scouring, ... 295
" Machines, ... 256
" Screens for, ... 264
(See also Smutters),
Scranton Coal, ... 116
Scraping Slide-Valve Seats, ... 174
Scratch Coat, ... 21
" Roll, ... 394

PAGE.
Screeching of Belts, ... 203
Screens, ... 273
" for Various Materials, . 256, 257, 262—264
" Harrington & Oglesby's Graded, . 264
" Punching, ... 257
" Perforated, ... 259
" Rolling, ... 257
" Plan for Rolling, ... 42
" Shaking, ... 257
" Sheet Metal,* . . . 260, 261, 262, 263
" Wire,* 258
Screw-Bolt Feeder,* 435
Screw-Drivers, ... 487
Screw, Lighter,* 316
Scubbing Burrs, ... 257
Seal-Oil, Action on Metals, ... 249
Seamless Cotton Sacks, ... 476
Seamless Steam Boilers, ... 131
Seams of Belts, ... 206
Secole Cornutum, ... 519
Secondaries, Number of, ... 323
Sectional Boiler Covers, ... 146
" Boilers, ... 119
" Plaster Boiler Covering, . . . 146
" View of Niagara Falls Mill and Elevator,* 49, 51
Section of Burr, ... 300, 303, 321, 373
" of Mill,* 465
" of Piston Head,* 182
Seed Coats of Wheat Berry, ... 513
Seeds, Sieves for, ... 273
Self-Oiling Journal Boxes for Shafting, . 192
" Post Journal Box,* 193
Semi-Bituminous Coal, ... 117
Semi-Tanned Belts, ... 200
Seneca Lake Mills, ... 38
Sensible Heat of Steam, ... 157
Separating Machine, Capacity of, . . . 256
Separation, ... 264
Separator,* 274
" Cockle Manufacturing Company, . 267
" Grader & Dustless, ... 273
" Place for, ... 256
" Richardson's Oat, ... 267
" Lubricants for, ... 245
" Screens for, ... 264
(Look also under "Cockle" and "Oats,")
Sergeant, W. E., Method of Getting Point of Suspension, ... 313
Set-Screws for Shafting and Pulleys. . . 198
Setting Driver-Boxes, ... 303
" Hopper Bevels,* 500
" of Boilers, ... 122, 134
" the Bed, ... 297
" Turbines, ... 99
Settling of Building, ... 10
" of Pillars, ... 14
Seven-Run Burr Mill, Richmond Works Plan of*, ... 67, 68
Shaft, Scarf-Spliced,* 195
Shafting, ... 188
" Barffing, ... 190
" Buying, ... 190
" Calipering, ... 189
" Clutch for Line, ... 196
" Cold-Rolled, ... 190
" Columns for, ... 19
" Couplings, ... 189, 193
" Cresson's, ... 188
" Diameters of, ... 188
" Directions, ... 40
" Fly-Wheel upon, ... 194
" for 450-bbl. Roller Mill, ... 42
" Haugers for, ... 191
" Hollow, ... 191
" Hot-Rolled, ... 190
" Improper Alignment, ... 177
" Journal Boxes for, ... 192, 193
" Keys for, ... 198
" Key Seats in, ... 193
" Line Coupling, ... 194
" Lining up, ... 198
" Oiling Coupling-Boxes, ... 194
" Scarf-Splice for, ... 194
" Self-Oiling Boxes for, ... 192
" Sizes of, ... 188
" Speed of, ... 191
" Springing of, ... 191, 192
" Torsion of, ... 193

PAGE.

Shafting, Turned, ... 188
" Wooden, ... 188
" Wrought-Iron, ... 188
Shafts, Distances of, ... 202
" Straightening Crooked, ... 522
Shaking Screens, ... 257
Shallow Corrugations, ... 394
" Grate Bars, ... 133
Shaly Coal, ... 117
Shape of Floats, ... 77
" of Boilers, ... 121
Sharpening Furrows, ... 353
Sharpness of Corrugations, ... 392
Shearing Action of Furrows, ... 332
Sheathing, Diagonal, ... 21
" Frame Buildings, ... 21
" Roofs, ... 23
Sheave for Wire Rope,* 237
Sheet-Metal Screens,* . . . 260, 461, 462, 463
Shell-bark Hickory, ... 117
Shells, Boiler, ... 121
Shell-Wheels,* 224
" " Bevel and Spur, ... 224
Shifter for Belts, ... 215
" for Fast-Running Machinery, . . 215
Shutters, Corrugated Iron, ... 20
Short Furrows, Number of, ... 323
Shoulders of Gear Teeth, ... 225
Sickle Dress,* 326, 336, 337
Side-Pull upon Spindles, ... 252, 257
Sieves, ... 255
" Testing, ... 475
" for Barley, ... 273
" for Cockle, ... 273
" for Corn Screens, ... 273
" for Flox, ... 273
" for Grain Cleaning, ... 273
" for Oats, ... 273
" for Receiving Riddles, ... 273
" Perforations for, ... 273
Silent Feed,* 314, 315
Silica in Wheat, ... 511
Simpson & Gault Mfg. Co.'s Cleaning Machines, ... 256
" Packers,* 477
" Grain Metres, ... 473
Single Cylinder Cockle Machine,* . . . 268
Single Leather Belts, ... 199, 201
" Link Conveyor,* 217
" Roll against Concave or Plane Breast,* 387
" Roll Acting against Curved Face, . 286
" Rolls, ... 386
" " Cost of Making Flour by, . . 523
" Roller Frame, Jones',* 388
" " Mills, Jones, Ballard & Ballard's, 387
Site, Mill, to choose, ... 9
Size and Weight of Stone, ... 296
Size of Burr Blocks, ... 288
" of Engines, ... 175
" of Pulleys, ... 201, 296
" of Shafting, ... 188
Six-Reel Chest,* 440
Skylights, ... 24
Slack Belts, ... 202
Slat Conveyor,* 217
Shcing Fires, ... 118
Slides of Steam Engines, ... 169
Slide-Valve and Automatic Engine Compared, ... 186
" " Engine, Cut-off, ... 174
" " Fitting to its Seat, ... 174
Sliding Friction, ... 243
Slip of Belts, ... 177, 202, 203, 204
Slippery Elm for Scaling Boilers, . . . 153
Slipping Pulleys, ... 234
" of Rubber Belts, ... 200
Sloped Roof, ... 22
Slow Combustion, ... 32
Smallest Roller Mill that it will Pay to Put up, ... 42
Small Semolina, Reels for,* 266
Smith, Geo. T., Purifier, Sectional View,* . 415
Smoke Connections, ... 126
" Consumer, McGinniss', . . . 136, 137
" Prevention by Draft Regulator, . . 142
Smooth Chilled-Iron Rolls, ... 287
Smoothness of Lands and Furrows, . . 336
Smooth Porcelain Biscuit Rolls, ... 287
" Rolls, ... 386, 390, 482
" " Action of,* 390

PAGE.

Smooth Rolls, Differential Speed of, . . 396
" " Power Required for, . . 391
" " Regrinding with, . . . 391
Smut, ... 518
" Machines, ... 257
Smutter,* 275
" Cost and Depreciation of, . . . 523
" Oil for, ... 247
" and Separator, Champion, . . . 274
" Screens for, ... 264
" and Separator, Setting up, . . . 276
Smutters, Lubricant for, ... 245
Snows, Roofs for, ... 23
Soapstone for Packing, ... 171
Soda Ash for Scaling Boilers, ... 153
" in Feed-Water, ... 147
" in Wheat, ... 511
Sodium Chloride in Wheat, ... 511
Soft Coal, Danger from Fire, ... 33
" Deposits in Boilers, ... 152
" Iron Rolls, ... 390
" Metal Bearings, ... 250
" Wheat, ... 381
" " Furrows for, ... 322
" " Grinding, ... 360
" " Rolls on, ... 394
" Winter Wheat, Rolls for, ... 395
" Wood, ... 116
Softness of Wheats, ... 523, 381
Southern Wheat, ... 525
Solid Friction, ... 243
" Gear-Wheels, ... 224
" Spur, ... 224
Soot causing Corrosion of Boilers, . . 150
" in Boilers, ... 153
Sounding for Wheel-Pit, ... 13
Southern Pine, ... 117
Space, Steam, ... 126
" Water, ... 125
Specky Flour, ... 322, 336, 432, 436
Speed of Belts, ... 201
" " Influence of, ... 199
" of Elevators, ... 219
" of Engines, ... 175
" of Gears and Pulleys, . . . 537, 538
" of Grinding, ... 359
" of Overshot Wheel, ... 78
" of Pulleys, ... 201
" of Shafting, ... 191
" of Steam Engines, ... 164, 165
" of Wheat Burrs, ... 482
Sperm Oil, Action of, on Metals, . . . 248
" " as Lubricant, . . . 245, 246
Spheres, Calculations, ... 537
Spindle,* 296, 298
" Coil Spring for, ... 251
" Expansion of, ... 359
" for Portable Mills,* 376
" Lubricant for, ... 245
Spindles, How to Order, ... 40
" Side-Pull upon, ... 252
Spiral Clutch, ... 195
" Coupler, ... 195
" Furrow, ... 325
Splice of Belts, ... 205
Splint Coal, ... 117
Split Pulleys, Cordial upon, ... 230
Splitting and Degermination, Ideal,* . . 372
Spontaneous Combustion, ... 31, 248
Spreading Device and Adjustments,* . . 404
Springing of Shafting, ... 191, 192
" of Walls, to Prevent, ... 13
Spring Wheat, American, Analysis of, . 511
" " " Bolting, . . 437
" " " Dress for, . . 342
" " " Purifier on, . 422
" " to take Oats from, . . 256
Sprockets for Detachable Link Chains, . 219
Spruce, Pine, ... 117
Spur Shell Wheels,* 224
" Wheels, Cost and Depreciation of, . 522
" " Solid,* 224
Square Feet of Heating Surface for Mills, . 37
" Inches of Water, ... 91
Squares, ... 487
Stable Equilibrium,* 307
Staff, Circular Iron, ... 349
" Red, ... 348
" Wooden Red,* 348
Staffing,* 348

PAGE.

Staffing and Picking, ... 344
Stamps, Rubber, Holderness & Co., . . 481
Standard Mill, Power Required, . . . 76
Standing Balance,* 307, 308
Starch in Wheat, ... 510
" for Scaling Boilers, ... 153
(See also Amidon.)
Staying of Boilers, ... 128
Steam Domes,* 129
" Generator for Wheat Heaters,* . . 280
Steam, ... 114
" Chest, ... 169
" Coils, ... 37
" Cylinders, Graphite in, ... 176
" " Lagging, ... 165
" " Material for, ... 168
" " Vacuum in, ... 161
Steam Domes, Le Van on, ... 128
" " Weakening Effects of, . . 128
Steam-Drum, ... 128
Steam, Dry, ... 138
" Economy of, ... 185
" Expansion of, ... 158
" High Pressure, ... 126
" Mechanical Effect of, ... 157
" Nature of, ... 157
" Performance of, ... 159
" Pressure of, ... 159
" Relative Admission Periods, . . 159
" Saving by Using Expansively, . . 161
" Superheated, ... 164
" Throttling, ... 161
" Using Exhaust for Heating Feed-Water, ... 147
" Wet, ... 125, 164
" Wire-Drawing, ... 161
Steam-Jacket Heater and Purifier, . 149, 164
Steam-Pipes, ... 138
Steam-Pipes for Fire Extinguishment . 37
Steam-Ports, Area of, ... 169
Steam-Power, Cost of Putting in, . . 185
" " *v.* Water-Power, . . . 75
" Pressure, Mean Effective, . . . 183
" Room, ... 127
" Space, ... 126
" Traps, ... 145
Steam Engine, ... 157, 177
" " Back Pressure in, . . . 162
" " Clearance in, ... 164
" " Compression in, ... 163
" " Condition of, ... 177
" " Corliss Type of Valve for, . 161
" " Cost of 50 Horse-Power, . 185
" " Cost of 100 Horse-Power, . 185
" " Cushioning, ... 163
" " Economy of, ... 177
" " Economy of High Pressure in, ... 162
" " Foundation for, ... 167
" " Governor Tests of, . . 165, 167
" " Measure of Economy of, . 162
" " Slides of, ... 169
" " Leveling Bed of, . . . 167
" " Waste of Power in, . . . 177
Steel Boilers, ... 119
" Bushes for Steam Engine Cylinders, . 168
" Connecting Rod, ... 170
" Crank of Engine, ... 170
" Hardening, ... 345
" for Picks, ... 345, 346
" in Wheat, ... 254
" Stepped Pulleys, ... 229
Steps, Lignumvitæ, ... 95
Steps of Turbines, ... 95
Stevens' Patents, ... 394
" Rolls, ... 389
Stencils, ... 481
Step, Drop-Lift,* 434
Stepped or Cone Pulleys,* 230
Stiff *v.* Oscillating Drive, ... 303
Stiffening of Single Leather Belts, . . 201
Stiffness of Journals, ... 250
Stones, Capacity of, ... 322
" Choice of, ... 521
" Dressing, ... 15
" for Middlings, ... 289
" for Rye, ... 288, 289
" for Ending, ... 257, 266
" for Hulling, ... 288
" Line of, in Niagara Falls' Mill,* . 53

PAGE.

Stones for Wheat, ... 288, 289
" Granite, ... 288
" Uneven Wear of, ... 315
Stone-Lift, Automatic, ... 316
Stone Piers for Penstock, ... 102
" Walls, Cost of, ... 15
Stoppages caused by Scale, ... 148
Stop-Valves, ... 127, 139
Storage, Floors for, ... 20, 481
" House, ... 10
" of Flour, ... 476
Straps, Heating of Eccentric, . . . 173
" Eccentric, ... 173
Straight Quarter Dress,* 325, 336
Straightening Crooked Shafts, . . . 522
Strainer, ... 143
Straw, Dirt, etc., Rules for,* . . . 265
Stream, Measuring Fall and Width of,* . 111
" Power, ... 111
Strength of Beams, ... 18
" of Boiler Plates, ... 120
" of Bricks, ... 16
" of Single Leather Belts, . . . 201
Stretching of Belts, ... 203, 204
" of Detachable Link Chains, . . 219
Stroke of Engine, ... 169
Strength of Flour, ... 476
Strong Flour, ... 517
Stuffing Boxes, ... 171
Submerged Orifices, Velocity of Discharge of Water through, ... 93
Sugar in Wheat, ... 510
Sulphate of Lime causing Foaming in Boilers, ... 147, 152, 153
Sulphate of Magnesium in Feed-Water, . 147
Sulphur for Hot Bearings, ... 244
Sulphuric Acid in Wheat, ... 511
Sulphurous Coal causing Boiler Corrosion, 150
Sumac for Scaling Boilers, ... 153
Superheated Steam, ... 164
Superheating Chamber, ... 139
Support of Floor Beams, ... 19
Supposed Path of Material, ... 321
Surface Grate, ... 131, 132
" of Rolls, ... 286, 390
Suspension, Methods of Getting,* . . 313
Sweeping Boilers, ... 126
System, Jonathan Mills'. 303
" Jones, ... 385
" Hungarian, ... 382
" Roller, ... 380
Systems and Processes, ... 379

TABLE for Weirs, ... 110
Table of Grate Areas, Barr's . . . 132
Table of Saving by Using Hot Feed-Water, 148
" Showing Saving by the Use of High Pressures in Steam Engines, . . 163
Taking Out of Wind, ... 350
Tailings, Reels for,* 444
" Rolls for, ... 394
Tail-Race, ... 94
" " Area of. 100
Tallow as a Lubricant, ... 245, 246
Tallies,* 478
Tally, Electric,* 479
Tallies, Barrel, ... 479
" W. N. Durant's, . . . 477, 478, 479
Tangential Force,* 307
Tanks, Capacity of, ... 34
" Weight of, ... 234
Tannic Acid for Scaling Boilers, . . . 153
Tar for Weevils, ... 520
Tarred Paper for Sheathing, ... 21
Tegumen, ... 513, 516
Tell, Lime of, ... 120
Temperature of Feed of Boilers, . . . 143
" of Fire. 117
" of Steam, Regnault's Experiments, . 158
Tempering Picks, ... 345
Templet Odontograph, ... 221
Tendency of the Heavy Side,* . . . 310
Ten-Run New Process Mill, ... 42
Tension, ... 199, 244
" of Belts, ... 202, 205
" of Wire Rope, ... 237
Terra-Cotta Arches for Floors, . . . 20
Tests, Expert, ... 177
Test of Boiler Plates, ... 119

PAGE.

Tests of Bricks, 16
" of Driving Power of Belts, 207
" of Governor, 166
" of Oils, 38
" of Steam Engine Governor, 167
" of Turbines, 86
" " by Herschel, 87
" of Water-Wheels by James Emerson, 86
" with various Dresses, 335
" in Holyoke Flume, 86
Testers, Flour,* 475
Testing Boiler Plates, 121
" Driving Power of Belts, 207
" Sieve, 475
" Strength of Belts, 207
Texas Pea, 256
Thermometer Attachment for Wheat Heaters. Durant's,* 281, 282
Thickness of Belts, Influence of, 199, 200
" of Gear Teeth, 225
" of Gear Wheels, 226
" of Mortar Joints, 17
Thin Belts, 200
Thousand-Barrel New Process Mill, 50
Three High Rolls, 286, 386
Throttle, New Form of,* 182
Threshing Machines, Screens for, 264
Three Hundred-Barrel Mill, Coal for, 187
Three-Run Mill,* 42—44
Throttle Valve, 180
Throttling Steam, 161
" and Wire-Drawing, loss by, 161
Throwing Over in Steam Engines, 169
Tightening of Belts, 177
" Pulleys for Belts, 202, 203
Tighteners for Detachable Link Chains, 219
Tilleda Stone, 288
Tilletia Caries, 518
Timber, Green, 19
" Joints.* 491
Time to Build, 14
Timothy, Screens for, 264
Tinfoil Packing, 171
Tin Roof, 23
Tin, Quantity to Cover Given Surface, 23, 24
Toope Boiler Covering,* 146
Tools needed, 487
Top-Lift Tram-Pots,* 301, 302
Torsion of Shafting, 193
Total Initial Pressure, 159
Total Heat of Combustion, 115
Towne, Horse-Power upon Tractive Force of Leather Belts, 233
Trachyte Burrs, 288
Tractive Force of Leather Belts, 233
Total Final Pressure, 159
Tram-Pots,* 301, 302
Trams, 487
Tramming and Bridging, 297
Transmission, 11, 188
" Advantages of Belt, 199
" By Chains, 216
" by Gearing, 220
" Long, 239
" Wire Ropes, 237
" by Pulleys, 229
Transparent Millstones, 320
Transportation, Cost of, 525
Trap Doors, 23
Traps, Expansion Steam, 145
Trier, Flour,* 475
Troubles in Grinding, 359
Trunnions, Main Valve of Wheelock Engine,* 182
Tubes, Draught of, 106
" Corrosion of, 131
" for Boilers, 122
Tubular Boilers, 122, 127
" Boilers in Limy Districts, 148
Tubulous Boilers, 124
Turbines, 80, 85
" Double, 95
" How to Order, 39
" Compared with Overshot,* 83
" Eels and Muskrats in, 96
" Bark in, 96
" Centre Vent, 81
" Clogging of, 96
" Dimensions of, 91
" Discharge of Water from, 82

PAGE.

Turbines, Draught Tube for, 94
" Flume for, 92
" High Heads for, 94
" Inward Flow, 81
" Leaves in, 96
" Maximum Velocity for, 81
" of Niagara Falls Mill, 48
" Outward Flow, 81
" Parallel Flow, 81
" Prices of, 91
" Rack for, 106
" at Saltillo, 95
" Sawdust in, 96
" Setting, 99
" at St. Blasieu, 95
" Steps of Lubricating, 95
" Tests of, 86
" Useful Effect of, 86
" *v.* Vertical Wheels, 73, 78
" Victor, 87
" Water Required by, 93
" Wheels, Ordering, 95
" Wooden Flumes for, 103
Turned Shafting, 188
Turpentine in Paint, 28
" for Bugs in Reels, 431
Twist of Corrugations, 395
Two Hundred and Fifty-Barrel Mill, Fuel Consumed, 187
Two Hundred and Fifty Horse-Power Steam Engine, Cost of, 185
Two Hundred-Barrel Mill, Fuel Consumed, 186, 187
Two-Run Burr Mill,* 42, 45
" " Noyes & Sons, 67
" Low Grinding Mill, 42
" Mill, Changing, 481
Two-Story Boiler, 122

UHLINGER Diamond Dresser, Patents, 355
Unburnt Fuel, Loss by, 115
Unconsumed Air, Loss by, 114
"Under Pressure," 163
Under-Runners, 285, 320
" " Lower Stone of Arndt's for Rye,* 339
" " Lower Stone of Arndt's for Wheat,* 340
" " Path of Material in, 321
Undershot Wheel, 77
Uneven Wear of Stones, 325
Units, Heat, 115
Unstable Equilibrium,* 307
Unsteady Water-Power, 96
Upper Bed-Stone,* 375
Upper Runners, Dresses for,* 325-330
" " Path of Material in, 320
Upright Penstock, 104
Uredo Linearis, 518
Uredo Rubigo, 519
Useful Effect of Turbines, 86
Use of Experts, 179
Using Draft Square,* 353
Ustilago Carbo, 518
" Maydis, 518

VACUUM in Steam Cylinders, 161
Value of Lubricant, 244
Value of Wood for Heating, 117
Valve, Blow-off, 145
" Check, 139
" Gear for Steam Engines, Corliss type, 161
" Motion, Uneven, 177
" Rod, 171
" Safety, 139
" Seat, Fitting Slide to, 174
" Seats, Scraping, 174
" Left-hand, 34
" Pop, 140
" Safety, 155
" Stop, 127, 139
" Throttle, 180
Various Grades of Burr-Stone, 289
" Millstone Dresses (Chap. xxiv., 319), 342
Variations of Power, 96
Variegated Burr-Stone, 288

PAGE.

Varieties of Roller Machines, . . . 386
Vegetable Glue, ... 509
" Grain Destroyers, ... 518
Velocity and Discharge of Water, . . . 107
" through Submerged Orifices, . . . 93
" Gauges of, ... 107
" of Steam, ... 127
" of Water, ... 107
" Ratio of Gear Wheels, . . . 225
Ventilating Action of Furrows, . . . 332
Ventilation of Buildings, ... 24
" of Millstones, ... 361
Vertical Belts, ... 199
" Cylinders, ... 169
" Fire Tube Boilers, ... 121
" Mill, ... 286, 320
" Shafts, ... 202
" Wheels *v.* Turbine, ... 78, 83
Vibrations caused by Horizontal Machinery, ... 10
Victor Turbine Wheel, ... 86, 87
" " " and Case, complete,* 90
" " " Case,* 88
" " " removed from Case,* 89
" " " set in Ordin'y Flume,* 92
Virginia Pine, ... 117
Volume of Air, ... 114
V-Toothed Roll,* 394

WALLS, Brick, ... 15
" Batter of, ... 17
" Cost of Stone, ... 15
" Hard Finish for, ... 21
" Holes in, ... 19
" Hollow Brick, ... 29
" Hollow Furnace, ... 115
Waste Steam, Utilization of, ... 149
Walnut, ... 116
Ward's Formula for Burr Dress, . . . 341
Washburn Mill, Height of, ... 11
Washburn A Mill, ... 205
" " Protection against Fire, 31
" B Mill, Magnets in, ... 254
" B and C Mills, Power Required, . 76
Washing-out Bailers, ... 152
" off Burrs, ... 353
Waste of Bricks, ... 17
" of Fuel, ... 117
" of Power, ... 75, 177
Water, Boiling Point of, ... 157
" Evaporation of, ... 116
" in European and American Wheats, 279
" Fall, Gross Power, ... 111
" Fall of, ... 107
" Falls, High, ... 95
" Flow of, in Turbines, . . . 81, 82
" Gates, ... 34
" Level, Varying, ... 77
" Lifting, ... 127
" Pipes, Fixed, ... 37
" Pumping Hot, ... 143
" Required by Turbines, ... 93
" Square Inches of, ... 91
" Trouble from Back, ... 79
" Velocity of, ... 107
" Weight of, ... 34
Water-Power, Cost of, at Various Places, 75
" " How to Order Wheel for, . 39
" " Measuring, ... 107
" " Measurement by Floats, . 110
" " Unsteady, ... 96
Water and Steam Power, Relative Cost, . 75
Water-Tube Boilers, ... 124
Water Spaces, ... 125
Water-Wheels (see under Overshot, Undershot, Breast, Spiral, Screw, Flood, and Turbine).
Water-Wheels, Gearing for, ... 86
" " Kinds of, ... 77
" " How to Order, ... 39
" " With Horizontal Axes, . 77
" " Ice in, ... 78
" " Reaction, ... 81
" " Building Overshot, . . 504
" " Buckets, Slope of, . . 77
" " in Cascade Mills, . . . 78
" " of New York Belting and Packing Company, . . 79

PAGE.

Water-Wheels, Work of, by Night and Day, 112
" " Governor for, A. W. Woodward's, ... 96
" " Shafts for Wing Gudgeons of, ... 196
Water in Wheat, ... 510
Watt's Rule for Grate Surface, . . . 131
Weakening Effect of Steam Domes, . . 128
Wear of Bearings, ... 245
" of Stones, ... 325
Webbing for Packing, ... 171
Weevils, ... 519
Weight of Air, ... 114
" of Bricks, ... 16
" of Leather Belts, ... 200
" of Materials (see under each material).
" of Pulleys, ... 229
" of Tanks, ... 34
" of Water, ... 34
" of Water in Flumes, . . . 103
" of Wood, ... 117
Weighting Burrs, ... 317
Weirs,* 109
" Table for, ... 110
" Measurement by, ... 108
Wells, Artesian, ... 34
West Virginia Burr, ... 288
Weston Differential Block,* 469
Wet Steam, ... 125, 164
Wheat Berry in Section,* 512
" Bran of Dry, ... 279
" to Take out Oats from, . . . 255
" Oregon, ... 254
" Southern, ... 279
" Treatment of Michigan, . . . 257
" to Purify Heated, ... 254
" to Take Oats from Spring, . . 256
" Quantity of Dirt in, ... 256
" Screens for, ... 264
" Brush, Capacities of, ... 278
" " Champion,* 277
" Cleaning Machinery, Inspection of, . 11
" Heaters, Steam, ... 279
" " Durant's Thermometer Attachment for, ... 279
" " Rice's Generator for,* 279, 281
Wheats, Water in, ... 279
" Dampening, ... 281
" Dress for Under-Runner,* . . . 340
" Foreign Prices in, ... 254
" Grinding, ... 295
" Reels for,* 443
" Stone for, ... 288, 289
" (Look also under sub-heads, as Winter, Mediterranean, Soft, etc.)
" Qualities of, ... 523
Wheel, Fly, ... 201
" Pit, ... 94, 99
" " Sounding for, ... 13
" " of Niagara Falls Mill, . . 53
Wheels, Gear, ... 224
" Water, etc., Niagara Falls Mill* . 52
" " (See also under Turbine, etc.) 77
Wheelock Engine,* 179, 180
" " Indicator Diagram from,* 178
White Burr, ... 288
" Oak, ... 117
" Pine, ... 117
Whiteness of Flour from Rolls, . . . 391
Whitewash for Grubs, ... 520
Wide Belts, ... 201
Width of Belt, Influence of, . . . 199
Wiebe's Dress,* 329
Willow, Hard, ... 116
Windows, ... 38
" Iron, ... 20
" French, ... 38
" to Lessen Effects of Explosions, 38
Wing Gudgeon for Water-Wheel Shafts,* 196
Winter Wheat, Cleaning, ... 256
" " Michigan, ... 523
" " Red Mediterranean, . . 525
Wire Binder, ... 254
" Bolting Cloth, "Acme,"* . . . 420
" Clothed Reels, ... 445
" Cloth for Engine Packing, . . . 171
" Drawing, Steam, Advantages of, . 761
" " and Throttling, Loss by, . 161
" in Wheat, ... 254

PAGE.

Wire Rope, Transmission, . . . 199, 237
" " Connecting Rod,* . . . 242
" " General Idea of Sheave,* . 239
" " Lining the Sheaves,* . . 240
" " Transmission,* 241
" Screens,* 258, 259
Wisconsin Water for Boilers, . . . 150
Wood, Air Required for Burning, . . 115
" Burnt in Mills, ... 187
" as Fuel, ... 187
" Charcoal, Air Required in Burning, 115
" Consumption of 100-bbl. Mill, . . 187
" Fuel causing Corrosion of Boilers, . 150
" Lagging for Steam Engines, . . 165
" Pulp Barrels, ... 476
" Weight of Cord, ... 117
Wooden Bearings, Graphite for, . . . 245
" Flume for Turbines, . . . 103, 104
" Gears, ... 221
" Pillars, Strength of, ... 19
" Red-Staff,* 348

PAGE.

Wooden Shafting, ... 188
Woods, Various kinds (See 116, 117, and under names of kinds).
Woodward, A. W., Water-Wheel Governor, 96
Wood-Working Machinery, Belts upon, . 202
Work of Bricklayer, per day, ... 16
" of Steam in Cylinder, ... 184
" of Water-Wheels by Night and Day, . 112
Wrought-Iron Boilers, ... 119
" " Journals, Bearings for, . 249
" " Shafting, ... 188
" " Rimmed Pulleys, . . . 202

YAEGER Mill, Plans of,* . . . 58, 61, 62
" " Loss from Fire in, . . 30
Yellow Burr Stone, ... 289
" Flour, ... 360
" Pine, ... 117

MILLER, MILLWRIGHT AND MILLFURNISHER.

CHAPTER I.

MILL CONSTRUCTION.

Site — Plans — Cost of Excavation — Foundations — Frost — Walls (Stone) — Bricks — Mortar — Batter — Partitions—Chimneys—Beams—Floors—Doors and Windows—Sheathing—Plastering—Roofs—Leaders — Skylights — Ventilation — Lightning Rods, Etc. — Paints — Fire-Proof Construction—Fires and Their Causes—Artesian Wells—Tanks—Pumps—Hose—Hydraulic Ram—Chemical Extinguisher—Fixed Water Pipes—Steam Pipes—Heating—Lighting—Estimates.

Site.—The first thing to do (if the site has not been already chosen), is to select a place for the mill. This is too frequently done without proper consideration and without regard to the probable effects of circumstances which become important factors in determining the success of milling enterprises. It is very difficult to find a place that has all the advantages of being near the wheat fields, just on the line of both railroad and water connection, with cheap freights from competition, handy for wagon transportation, with good outlet for the products, cheap fuel, or plentiful, unfailing and cheap water supply, in such a situation as to make the expense of installing the water-wheel low, and all the other items which go to give one mill an advantage over another. These things must all be taken into account. But the site once chosen, the next thing is to draw the plans.

Plans.—What the plan is to be will be determined by what the motive power is to be, the kind of wheat to be milled, whether the mill is to be for custom or merchant work, or both combined; where the motive power is applied and in what manner; which process or system of milling you have determined upon; how the wheat is to be received, whether you are to store great quantities of it or not; how the products are to be got out. There is no investment that brings so good a return as a good set of plans. They save labor and material in erecting the mill and power and labor in running it. Choose the process to suit your condition, the machinery to suit the power, and the mill to fit the machines.

The draught of the mill should first show every wheel, shaft and machine and their places, and after this the windows and doors, etc., can be placed. The most expensive mill is that which is built without a plan. It is much easier to correct a mistake on paper than when in wood, stone or metal. The mill should not be planned or built too hastily. The building should be adapted to the machinery it is to contain. Not a blow should be struck before the whole mill is drawn on paper. In planning, the following elements should be considered: Whether the mill is to be steam or water driven,

yard, measured in place (an average cart load), of sandy soil in five minutes; loam six minutes; any of the heavy soils, seven minutes. This would give, for a day of ten hours, 120 loads, of 40 cubic yards, of light, sandy soil; 100 loads of loam; or 86 loads of heavy soils. Deducting two-fifths time lost, the actual work is 24 yards of sandy soil; 20 of loam; or 17.2 of heavy soil. The cost, at $1 per day, is thus: For sandy soils, 4.167 cents per cubic yard; loam, 5 cents; heavy soils, clay, etc., 5.81 cents. Next, as to hauling, dumping and returning. Horses travel, in hauling, 2½ miles per hour, or 200 feet per minute—100 feet, trip each way. There is a loss of 4 minutes in every trip for delay. Thus, to find the number of trips per day over any average lot, divide the number of minutes in a working day by the sum of 4, added to the number of 100 feet lengths in the lot. One driver attends four carts on ordinary leads. This is 25 cents per cart. When labor is $1, the horse is generally 75 cents including Sundays and rainy days. Spreading.—For cellar work this is seldom done. The bank men will spread 50 to 100 cubic yards per day, say 1½ cents for heavy soils and 1 cent for light. For keeping the road in good condition for hauling as the ruts and puddles should be filled, &c., allow 1-10 cent per cubic yard per 100 feet of lead. Wear, &c., will be covered by ¼ cent per cubic yard. Superintendents and water-carriers should be covered by 1½ cents per cubic yard. Wheelbarrows.—Men with barrows move about the same as horses. The time of emptying is about 1¼ minutes, and, in all, we may say that a man works only nine-tenths of his time. To find the number of barrow loads per day per man, multiply the number of minutes (600) in a working day by 9, divide the product by 1.25, the number of 100 feet lengths in the land; divide the number of loads by 14 for the number of cubic yards, since the cubic yard, measured in place, makes 14 barrow loads. Removing rock excavations by barrow.—A cubic yard of hard rock in place weighs 1.8 tons if sandstone or conglomerate, and 2 tons if good compact granite, gneiss, limestone or marble. Broken up, the solid yard takes up 1⅘ cubic yards. Earth swells to only one and one-fifth its ordinary bulk. Such a cubic yard will weigh 1.09 tons; then a barrow load of 2.31 cubic feet of loose earth weighs 174 lbs. We may say that a barrow of loose rock should weigh 177 lbs. and take up 2 cubic feet of space. For loosening hard rock allow 45 cents per cubic yard in place. Soft shales may be loosened by pick and plow for from 15 to 20 cents; others may cost $1. Quarrying hard rock takes ¼ to ⅓ lb. of powder per cubic yard in place; sometimes ½ lb. A good driller will drill 9 to 12 feet deep of holes, 2½ feet deep by 2 inches diameter, per day, in average hard rock, at from 12 to 18 cents per foot. Removing rock excavations by carts.—A cartload of rock is ⅓ cubic yard in place, weighing, say, 851 lbs. As the cart weighs ½ ton, the loads of rock and of dirt are very nearly the same.

Foundations.—The character of foundations is as important a subject as can be studied in connection with mill building, and we fear that too little attention has been paid to it. The foundation should be thoroughly tested with an iron rod or pump auger, to ascertain if the soil is firm. In starting the masonry the large stones should, of course, be placed at the bottom of

the pit, so as to equalize the pressure as much as possible, and they should be carefully bedded, so that they cannot possibly rock. Where a mill is built in front of a race, with a yielding bottom, which would be liable to wash away in freshets, the entire bottom should be covered with a deposit of rough, angular quarry stone, the largest ones being at the outside. In locating a mill, the general outlines for the plan of the village, which is often erected for the accommodation of the manufacturing population, should be fixed upon. The requirements of the little colony, which is frequently formed around the waterfall which turns the mill wheel, should be considered, in order that there may be an agreeable arrangement of the dwellings.

The whole extent of the waterfall should be in the first instance located and improved as far as practicable, as water power is always valuable; and permanent bounds should be erected at the height of the ordinary level of the water in the mill pond to serve as landmarks of possession, should mills be afterwards erected in the same vicinity. Before fixing upon the immediate spot for sinking the wheel pit, the earth around it should be carefully sounded by a pointed iron rod, as before mentioned, to ascertain if there are ledges of rock which might obstruct the necessary excavations, as by changing the location only a few feet obstructions of this sort may commonly be avoided. Although it is desirable to place the foundation of a mill upon this solid basis, yet a little attention to this may save the subsequent expenditure of large sums, which are very frequently lost by the costly excavations in flinty rocks. In laying out the ground plot for stone or brick mills the trenches should be staked out considerably larger than the intended size of the building to allow of the projection of one or two feet for the foundation stones, which, on loose soil, should extend considerably beyond the outer face of the main walls. If the lower courses of stone work, intended for the foundations beneath the surface of the ground, be three feet wider than the wall above it, then two feet of the projection should extend beyond the outer fronts of the walls and only one foot within them. Walls of buildings have always a tendency to spring off or outwards, but are effectually prevented from falling inward by the floors. Even after the utmost caution has been bestowed in laying the foundations of a mill with large heavy stones, the walls should be secured to the ends of the beams by iron clamps or screw bolts and plates, to prevent them from springing outward. Walls sufficiently strong for warehouses have been found to yield at last to the constant tremor produced by the reciprocating motions of machinery and the violent sudden thrusts occasioned by the irregular action of the teeth of wheels.

The arches above the flume and race of a mill, unless constructed near the centre of the building, with each wing to serve as a buttress, are always inclined to yield to the weight pressing upon them, whereby one of the buttresses forming the end wall is commonly crowded off. The tremor of the walls affects the stones of the arch, the least yielding or opening of which allows the keystones to operate in an instant like so many wedges to prevent the span from recovering its former place, whereby the walls soon become seamed with unsightly cracks. It is better to form two small arches, or to support the centre by stone pillars, than to form one large span.

When the soil is composed of loose sand or clayey loam, the walls of the wheel pit should be founded upon piles, and in most cases it is common to extend the planked floor of the wheel pit sufficiently for the surrounding walls to be based upon it. Indeed it may be adopted as a general rule that it is true economy to construct all parts of the foundations of mills in the strongest and most solid manner.

The posts which support the beams in the centre of a mill should also rest upon a very solid mass of masonry, as the lines of shafts and other mill gearing are either attached or dependent upon them for maintaining their proper situations. The settling of a pillar in the basement of a mill merely one-half of an inch will derange all the lines of horizontal shafts in every story above, whereby vast stress is thrown upon the couplings, and all the revolving wheels connected with such shafts immediately begin to wear irregularly and to produce a clattering noise. If a block of hewn stone be used in any part of the structure, it should not be omitted here. Cast-iron pillars or posts are generally used in England, and as they are cast hollow, like water pipes, they are not very expensive.

Great care is bestowed in laying the most solid foundations of hewn stone, to sustain the working parts of the steam engines and water wheels, in the best foreign mills. Blocks of split granite, plumber blocks and other heavy fixtures for water wheels may be formed of granite at an expense which will not prove eventually much greater than if formed of timber, a material which in such situations is very liable to rapid decay. In setting up water wheels and steam engines, particular care should be given to the construction of the framing—which sustains the first impulse, or immediate action of the moving force—as independent of the walls and floors of the mill as possible, in order to avoid imparting to the whole building the tremor which is frequently so great as to be communicated in a very perceptible manner to the ground upon which the building rests.

Frost.—One of the most difficult problems which present themselves to architects and builders is the determination of the question, how soon mason work ought to be stopped on account of frosts. For extensive buildings, the erection of which will, at the best, occupy several seasons, the ordinary rule of covering over the walls from November to April is well enough; but in smaller structures, such as dwelling-houses and mercantile buildings, where every day's delay involves a money penalty or a loss of rent, it is of great importance to continue operations as long as is consistent with safety. In practice, many contractors never cease building as long as the mortar can be made to remain unfrozen long enough to spread it; but this course involves great risk, not perhaps of the failure of the walls so constructed, but because of the danger of permanently weakening them, and rendering them porous and permeable to moisture. A brick or stone chilled by cold weather, and laid even in hot mortar, condenses the moisture on its surface, where it freezes, forming a film of ice between itself and the bed of mortar, which, unless very soon thawed again before the lime begins to harden, effects a permanent separation between the brick and the mortar, so that it can be lifted from its bed after the masonry is dry, without

the mortar's adhering to it. If a wall so laid is exposed to the sun, so as to thaw one side partially, it will bend toward that side, sometimes to a serious extent. Cement, although useful for cold weather work on account of the rapidity with which it hardens so as to be out of danger, is very injuriously affected if frozen too quickly, the "initial set" being so broken up as to prevent subsequent induration. No doubt the safest mode of conducting winter work is to heat the brick or stone by piling them in a sheltered place near a stove. The warmth which they slowly acquire is retained for a very long time, especially in the interior of walls laid with them, and a superficial freezing, if it should take place, is easily remedied by pointing when milder weather returns.

Walls.—The walls may be constructed of stone, concrete, brick or wood frame. Of these four, brick is the only one which is in any degree fire-proof. The cost of stone work may be divided into getting out from the quarry, dressing, hauling, mortar, and laying—including scaffold, &c. The cost of stone after getting the quarry, cleaning off the top earth to the disintegrated top rock, and providing the necessary tools, trucks, cranes, &c., may be divided as follows: Stones of such size as two men can lift, measured in place, cost about as much as from one-fourth to one-half the daily wages of the quarry laborer. Large stones, of dimension from one-half to one cubic yard each, on which most of the work must be done by wedges, to make them true to shape and dimensions, cost from two to four daily wages per cubic yard. (The smaller prices are low for sandstone and the greater are high for granite.) One and one-third cubic yards of good sandstone can be got out at the same cost as one of granite; that is, calling the price of granite 1, that of sandstone will be $\frac{3}{4}$; so that the prices given are full for sandstone, scant for granite, and about fair for limestone or for marble.

The waste in dressing stone will be from one-sixth to one-fourth of the rough block, in the best cases. In blocks of half a cubic yard each got out by blasting, one-fourth to one-third will not be too much for medium stone. It is better to dress at the quarry, so as to save transportation. A stone cutter will take out of wind and patent hammer dress 8 to 10 square feet of plain face in hard granite in eight hours, or twice as much of the dress given butts and joints. In good sandstone or marble he can do about one-fourth more.

In estimating the cost of ashlar facing masonry, stones, say 5 × 2 × 1.4 feet thick, equal to $\frac{1}{2}$ cubic yard each, will cost for granite or gneiss:

Getting out the stone from the quarry by blasting, allowing one-fourth for waste in dressing, $1\frac{1}{3}$ cubic yards at $3 per cubic yard,	$4.00
Dressing 14 square feet of face at 35c.,	4.90
" 52 " " butts and joints at 18c.,	9.36
Net cost of the dressed stone at the quarry,	$18.26
Hauling, say one mile, loading and unloading,	1.20
Mortar,	.40
Laying, including scaffold, hoisting, machinery, &c.,	2.00
Net cost,	$21.86

With stones of a smaller size than that before mentioned there will be more square feet of dressing per cubic yard.

Following is the estimated cost of large scabbled masonry:

Granite rubble, stones ½ cubic yard each, cost for getting the stone from the quarry by blasting, allowing one-eighth for waste, 1 1-7 cubic yards at $3,	$3.43
Hauling one mile, loading and unloading,	1.20
Mortar (2 cubic feet or 1.6 struck bushels of quicklime and 10 cubic feet or 8 struck bushels of sand or gravel, and making),	1.50
Scabbling and laying, including scaffold, hoisting, machinery, &c.,	2.50
Net cost,	$8.63

Bricks.—A good hand-pressed brick, 8¼ × 4 × 2 inches, weighs 4½ pounds, or 118 pounds per cubic foot. A machine brick of the same size weighs 5 pounds. Either of them will absorb half to three-quarters of a pound of water. Brick work may be put at 1.4 tons per cubic yard, 1.3 tons per perch of 25 cubic feet, or 116 pounds per cubic foot; or for machine-molded bricks, 1.56 tons per cubic yard, 1.44 tons per perch, and 129 pounds per cubic foot. Allowing for waste in cutting to fit corners, jambs, &c., the average number of 8¼ × 4 × 2 inch bricks per square foot of wall is:

Thickness of Wall.	No. of Bricks.	Thickness of Wall.	No. of Bricks.
8¼ inch or 1 brick.	14	21½ inch or 2½ bricks.	35
12¾ " 1½ "	21	25¾ " 3 "	42
17 " 2 "	28		

A bricklayer, with a laborer to keep him supplied with materials, will, on common walls, lay about 1,500 bricks in ten hours; in neater faces, about 1,000 to 1,200; in straight fronts, 800 to 1,000; in large arches, 1,500 or 3 cubic yards.

Good, well burnt bricks will ring when struck together. A soft brick will crush with 450 to 600 pounds per square inch, or 30 to 40 tons per square foot, while a good machine-made brick will require about 6,222 pounds per square inch, or 400 tons per square foot. This last is about the same as the best sandstone, two-thirds as much as the best marbles or limestones, and one-half as much as the best granites. But masses of brick crush under less pressure than single bricks. Small cubical masses, 9 inches on edge, laid in cement crushed under 27 to 40 tons per square foot. Piers, 9 inches square, 27 inches high, in cement, require 44 to 62 tons to crush them; but cracking and splitting commence under about one-half the crushing loads. To be safe, the load should not be more than about one-eighth or one-tenth the crushing load.

Bricks should be of regular size, color and shape, with sharp edges and corners, and should give a clear metallic ring when struck together. They should break clean and show an even grain, without any stones or

large pores in them. Most machine-made bricks are heavier and stronger than hand-made.

Mortar.—Mortar is made of about one measure of quicklime (lump or ground) to five measures of sand. The bulk of the mixed mortar exceeds that of the dry loose sand alone about one-eighth. Allowing for waste, 20 cubic feet or 16 struck bushels of sand of 4 cubic feet and 3.2 struck bushels of quicklime (measure slightly shaken) make about 22½ cubic feet of mortar, sufficient to lay 1,000 bricks, 8¼ × 4 × 2 inches, with the joints used in inner walls (varying from ⅜ to ½ inch). With such joints 1,000 such bricks make 2 cubic yards of massive work, and nearly one-third of the mass will be mortar. For outside joints, more lime is used; say one in four or even one in three parts. For cellar walls of stone rubble, one measure of lime to six or eight of gravel is used. A cubic yard of rubble requires as much mortar as 500 bricks of the size given above; or 10 cubic feet is equal to 8 struck bushels of sand and 2 cubic feet or 1.6 bushels of lime. The best laid rubble will contain only one-fifth of its bulk of mortar, or 5½ cubic feet of sand and 1.1 cubic feet of lime per cubic yard. To resist dampness, hydraulic lime should replace one-third of the lime. If exposed to water, still more cement should be used. With bricks 8¼ × 4 × 2 inches, the quantities of mortar, as compared with the whole mass, to the number of bricks required for a cubic yard of massive work should be in the proportion stated under:

Thickness of Joints.	Proportion of Mortar in the Whole Mass.	Number Bricks per Cubic Yard.	Number Bricks per Cubic Foot.
⅛-inch.	About 1-9	638	23.63
¼ "	" ¼	574	21.26
⅜ "	" 3-10	522	19.33
½ "	" ⅓	475	17.60
⅝ "	" 4-10	433	16.04

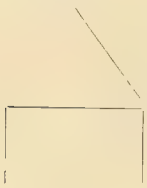
Allow 2 or 3 per cent. of the brick for waste; in common buildings 5 per cent. or more. Common lime mortar exposed to constant moisture will never harden; cement does. Fine brickdust or burnt clay improves common mortar and makes it hydraulic. The crushing force of good mortar is about 50 tons per square foot, or 777 pounds per square inch.

Batter.—The walls of each story should be a little lighter than those of the story below, and the foundation should be heavier (that is, much thicker and stronger) than the wall which it supports. Thus, a 14-inch wall should have an 18-inch foundation. A good way, for many reasons, is to give the foundation wall a batter or slope, the inside being straight and the outside having all of the batter. Where each wall is slightly heavier than the one above it, the outside face should be flush. The corbel or inside ledge can serve in part as the support of the floor beams.

Hollow Brick Partitions.—Some idea of the value of hollow bricks in fire-proof constructions can be drawn from the following report of experiments, attested by numerous architects and insurance officers in New York: In a building with wooden beams and rafters, a fire of pine and hickory

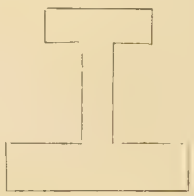
logs, kerosene and shavings, was maintained for one hour and then put out. On examination the floor beams and ceiling rafters were found to be even undiscolored by the heat. A Mansard roof, laid on wooden rafters and lined inside and out with hollow bricks, sustained a fire of logs and kerosene on both sides for thirty-five minutes without injury or even discoloration. Some pieces of pine wood were placed in a hollow brick, the ends of which were stopped with cement. The brick was then placed in the fire and kept there for thirty-five minutes. On being taken out it was found to be uninjured. Experiments with wood shavings, paper, etc., showed similar results.

Chimneys.—These will be spoken of more fully under the head of boilers. Chimneys, which are intended simply as smoke passages for a heating apparatus, demand much less science in their design and erection than those intended for boilers. In a brick or stone mill they should form a part of one of the outer walls. Where they have any considerable height above the rest of the building they should have an extra foundation to bear the extra weight. They should be built plumb and true, with close joints, well laid up in good mortar, and with none of the mortar projecting on either the inner or the outer face, as any roughness tends to retard the upward passage of the products of combustion. The higher the chimney the better the draught. If a chimney is placed at the windward side of a building, in such a place that it will receive a reflected current from a crest, or if it is in any place where it is liable to receive such a reflected current, it must be made sufficiently high to prevent a high wind from blowing the smoke down it. There are places where it is necessary to have a cowl to assist the draught; but in most places it is enough to have a very simple contrivance of brick work, so placed that the upward draught of the chimney will have more force the stronger the wind blows. Such a structure will be something like the diagram shown; with the open side of the gable to the prevailing wind. If there is no prevailing wind and the draught is poor, then a revolving cowl must be used. Of this there are many samples and many excellent patterns.



Strength of Beams.—Calling the breaking load of a beam, firmly fixed at one end and loaded at the other, 1; when evenly loaded it will be 2; when merely supported at the end and loaded at the centre, 4; supported at the ends and with the load evenly and uniformly distributed, 8; firmly fixed at the ends and loaded at the centre, 8; if uniformly loaded, 16.

The Hodgkinson beam is nearly one and three-quarter times as strong as an ordinary beam of equal weight, with both flanges alike. As cast iron requires six and a half times as much weight to crush it as to pull it apart, in the Hodgkinson beam the upper or compressed flange has only one-sixth the area of the lower one. Thick castings are proportionately weaker than thin ones. For very long beams half the weight of the beam must be deducted to get the net breaking load. Where the weight is evenly distributed, the breaking weight will be twice as



great. Cast beams must always be tested. The strength of wooden pillars and beams depends upon the seasoning. This should be borne in mind in building with green timber, for seasoned timber has often twice the strength of green.

One precaution that is very seldom taken with high buildings is so supporting the timbers of the floor that in case they break or fall they shall not pry the wall over inward, and that in case they expand they will not push it over outward. As ordinarily constructed, holes are left in the walls into which the ends of the joists are set, the holes being about the size of the ends of the joists, so that in case the floor falls the timbers are apt to tumble the walls inwards on the contents of the building. There are two ways of getting around this. One is to set the end of the joist upon a corbel or projection from the face of the wall so that the joist will clear the face of the wall entirely, and in case of fall exert no influence upon the wall. The other method has the same object in view and accomplishes it by a simpler method. The holes to receive the joists are made about twice as high as the joists, so that in falling the joists have no prying effect upon the wall. These remarks apply to iron as well as wooden beams; but for iron beams there should be the additional precaution to leave a greater space between the end of the beam and the wall, so that the inevitable expansion of the beam from fire shall not cause an outward thrust tending to overthrow the walls. It would perhaps be as well if all external walls were held together by anchor bolts with external plates, which, although not very sightly, often help to hold the wall up when otherwise it would topple and fall outward. Of course, if the beams are properly cased below with some fire-proof material or by some heat-proof method, their expansion will be very much less than if they are left naked to the action of the heat.

Floors.—The longer lumber is seasoned the better will it be, and it will give less trouble by checking, warping, sagging, and shrinking. Air or water seasoned lumber is better than that which has been kiln-dried. Making beams strong enough not to break does not provide against their sagging. All wooden floor beams should be sawed and set on a "camber," that is, with a slight rise in the middle, and when the weight is put on them they will settle to a level. The greener the timber, the more camber will have to be given. The upper floors must be more cambered than the lower. Depth, rather than thickness, gives strength and stiffness to floor beams, and they may be greatly strengthened by plenty of cross braces, which cost little but add greatly to the stiffness and strength of the floor. Any sagging in the mill throws all of the machinery out of line and consumes power.

Where posts are employed to hold up floors, they should be as stiff as possible, but they must not be made to take up too much floor space. This does not mean that they must be of small section, but they shall be disposed so as not to prevent the proper arrangement of machines. Really, the floor plans should be laid out as though it was possible to get one large floor that would not need posts; and then the posts should be made to conform to the machinery. If the floor beams are made stiff and are well scarfed and properly supported, the columns can be shifted when the mill or

machinery is altered, without greatly interfering with the strength of the building. Floors for storing flour must be extra strong, as the weight is extremely concentrated.

As fire-proof floors are necessary features of construction in a first-class mill, some figures of their weights and prices will be found useful in making estimates. For ordinary spans between beams of, say, 5 to 6 feet, there are generally used 6-inch flat arches of either lime of Teil, or hollow burnt terra cotta in 5-feet spans, and 8-inch arches of same description in 6-feet spans. These flat arches offer a flat surface on both top and bottom sides, and, therefore, give a flat ceiling, left ready for plastering. Their comparative weight and cost, compared with ordinary solid brick segmental arches, filled up with concrete above them, are as follows:

Description.	Weight per Square Ft.	Price Put Up in Philadelphia.
6-inch lime of Teil flat arches, ...	22 lbs.	27 cents.
6-inch burnt terra cotta, ...	34 "	28 "
8-inch lime of Teil flat arches, ...	28 "	30¾ "
8-inch burnt terra cotta, ...	42 "	33 "
Segmental ordinary arches with concrete filling,	65 "	20 "

The great lightness of the flat arches, and the fact of their presenting a flat ceiling, all ready for plastering, has caused them to supersede very largely, in first-class buildings, the ordinary segmental brick and concrete filling arches that load the beams for no needful object, and present when erected curved surfaces between beams, ⌒⌒⌒⌒; which construction admits of a very ordinary and plain finish.

Iron Doors and Windows.—Few buildings stand in greater danger of fire than grist mills, and yet very few mills have anything like adequate protection therefrom. Window openings, while they give outlet to flame, give inlet to air which carries a fire further and with greater force. The flames from one window set fire to the one above, and so on. It should be made imperative that the doors and shutters of a mill shall be fire-proof. To take down the windows and coat them with a thin sheet-iron looks all well enough, but a real fire passes by such trifles. Thin sheet-iron gets red hot in a minute, and the wood readily chars, affording protection merely for a moment. Of course the next best thing is to make them of iron, stiff enough to need no reënforcing of wood. But here comes in another difficulty; this iron warps and twists under the action of fire; and even if it does not cause great loss by fire direct, the shutters are useless after the fire, and must be thrown away. To make matters better, corrugated iron shutters are employed, because they are much stiffer and stronger, besides being more sightly. But even they have this disadvantage, that iron is a good conductor, and they speedily get red hot on both sides, so that a fire from the outside may set fire to combustible material inside, even with the shutters closed.

The next step toward the perfection of fire-proof shutters is to make air chambers between two corrugated walls, thus giving greater stiffness, and at the same time preserving one side from destruction or great heating by the non-conducting layer of air between. Such a shutter is at once more fire-proof and more burglar-proof than any of the others indicated. In some cases the principle is carried still further by employing three corrugated sheets, thus giving two air spaces, and securing greater strength. In these last two modes of construction one of the sheets is larger than the others, so as to form a flange that will completely cover the opening of the window, thus making at once a neater job and one more fire-proof and better adapted to resist burglars. All openings in the walls of buildings that contain valuable matter and are subject to fire should be covered by such double or triple corrugated iron screens. Where there is an opening between two buildings, or between two compartments of the same building, or in any case where the opening is a large one,—the door should be a sliding one, as no amount of twisting or warping could make it give so as to admit flame or a burglar. The corrugated sheets may be galvanized, or they may be protected by three or even two coats of good metallic or other resistant paint, which will keep them from damage or destruction by rust.

Sheathing.—All frame buildings should be properly sheathed to secure warmth and dryness. One way of effecting this is to use diagonal inch boards over all the studding before the weather boards are put on. The diagonal boards have the advantage of making the building much stronger and stiffer than it would be if there were no such braces. This point alone would make it worth while to sheathe a building with boards. The diagonal boards may be supplemented with tarred paper or its equivalent run lengthwise vertically. The quantity of boards required to sheathe an ordinary frame building is somewhat in excess of the exact superficies of the sides, by reason of the small quantities cut off on the sides and over windows and doors. Filling is often resorted to between the sheathing and the plaster. Frame buildings may be filled with brick, rubble, or concrete, which of course tends to increase the weight and stiffness of the walls as well as their thickness.

Plastering.—There should generally be given three coats of mortar—first the rough or scratch coat of one measure of quicklime to four of sand, and one-third of hair to increase adhesion. This coat, three-eighths to one-half inch thick, is put on roughly, and should be well troweled and clinched behind the laths—which last should be no nearer together than half an inch. When nearly dry this first coat is scratched with a pointed stick in lines two inches apart. These scratches hold the second coat, which is of the same material as the first, but from one-fourth to three-eighths of an inch thick. Before it is dry it is roughened by a hickory broom, to hold the third coat. The third coat, of only one-eighth of an inch thickness, contains no hair but more lime, or one measure of lime to two of sand. Instead of this, the outer coat may be a "hard finish," made of one measure of ground plaster of paris to two of quicklime, and no hair. A good effect is produced by only two coats of plaster, in which fine, clean, screened gravel is used instead of

sand. As salt would make the walls damp, care must be taken not to get plaster hair from salted hides nor to use sea sand. Where a brick wall is to be plastered the joints should be left very rough, that the mortar may hold. When put on smooth walls the mortar should first be well raked out. A plasterer, with one or two laborers for mixing and supplying the material, can average from 100 to 200 square yards a day of first coat; two-thirds this quantity of second, and half as much of third.

Plastering laths are generally of white or yellow pine, either three or four feet long, one and a half inch wide and one-fourth inch thick. They are nailed up horizontally, a half inch apart. The distance between the joists is generally fifteen inches between centres, so that the ends of the laths may be nailed to them. Laths are sold either by the bundle or by the thousand. A square foot of surface takes one and a half 4-foot laths; that is, 1,000 laths cover 666 square feet. A good carpenter can nail up forty to sixty square yards in ten hours. The following table gives the cost of plastering:

Material.	Three Coats Hard Finished Work.		Two Coats Slipped Coat Finish.	
Quicklime,	4 casks,	$4.00	3½ casks,	$3.33
" for fine stuff,	⅔ "	0.85		
Plaster of paris,	½ "	0.70		
Laths,	2,000,	4.00	2,000,	4.00
Hair,	4 bushels,	0.80	3 bushels,	0.60
Common sand,	7 loads,	2.00	6 loads,	1.80
White sand,	2½ bushels,	0.25		
Nails,	13 lbs.,	0.90	13 lbs.,	0.90
Masons' labor,	4 days,	7.00	3½ days,	6.12
Laborer,	3 days,	3.00	2 "	2.00
Cartage,		2.00		1.20

Roofs.—The roof of any building should be designed with a view to utility, after which questions of cost or of beauty may come in the order which bests suits the owner. In mill building, the attic is generally used for some machinery or other, and hence the elevation of the building should not be planned until the floor plans are laid out with special reference to the machinery which is to be employed at first and subsequently. A little head room in the attic costs very little when it comes right down to a question of rafters and slate. Extra height of the attic means at the most only a little extra cost for wall, if a certain pitch of roof is determined upon; but if the wall height is decided, a little steeper pitch of roof by slightly longer rafters will give more light and head room with but little cost, beside shedding rain and snow better than the flatter pitch. There is one thing to be borne in mind—the pitch and the material of the roof ought to agree. A slate roof will not bear to be made flat, nor a gravel and tar one steep. If the roof is of slate, the rafters must be made heavy enough to bear the extra

weight of the heavy covering. If there are snows that come to stay, flat roofs of no material will answer well. It must be remembered also that the roof is one of the first points attacked by fire from without and one of the most common means of spreading fire from either within or without. If put on in a windy locality, it must be more securely fastened on than in a locality where there are no high winds. Every roof should be put on with a view to be raised one or more stories at some time or other, for it often happens that it becomes absolutely necessary to have more room in the mill, and that land cannot be bought at any price. If the foundations are strong and the walls heavy enough to bear the weight of another story, and the roof stiff enough to bear lifting, so much the better. In every case there should be ample provision made for getting out on the roof in case of fire, and for inspection, &c. It is very easy to arrange trap-doors for egress, with ladders for getting up to or down from a roof; and while these do not cost much at first, they are—especially the trap-doors—somewhat expensive to add afterwards.

Of course, the pitch of the roof must be made to correspond not only with its material, but with the general style of the building, with the climate, with the uses to which the attic is to be put, &c. Other things being equal, the colder the climate, and the greater the liability to snow upon the roof and to driving storms, the steeper the pitch of the roof should be. There is, however, a certain limit to this; as, the steeper the roof is, the greater the resistance to high winds, the greater the weight put upon the walls, and the greater the liability of the covering being torn off.

A flat roof never means a roof that is exactly flat, but one with but little pitch. This style is but little suited to districts where there is much or any snow fall, as the snow will lie for a long time upon it and is apt to leak through, in time of thaw, even if it does not by its great weight crush the timbers and covering. A flat roof has the advantage of being cheap to construct, as to both material and labor.

The tin roof, so called, is a covering of tinned sheet-iron; at least, it is nominally tinned sheet-iron, although lead enters more largely into the composition than the higher priced tin. Owing to the utter refusal of tinners to adopt improved and money saving methods of putting on so called "tin" roofs, the old fashioned system of using small sheets of tin, which must be carefully bent up on the edges and soldered in place, still remains, although a much cheaper and tighter roof can be made from the continuous rolls of tinned iron supplied by some English manufacturers. The table on next page gives the size, quality and weight of tin sheets used in roofing. The quantity required of each size to cover 1,000 square feet is given, and the number of square feet that a box of each size will cover. It should be remarked that the tin covering of roofs should receive a coat of good resisting metallic paint, ground in oil, applied above and below.

The iron roof, familiarly so called, consists of an iron covering on a wooden frame work. As generally applied, the purlins are sheathed with board (sometimes with both board and sheathing paper or felt), and then the rolls of sheet-iron, properly painted on both sides, are applied in such a manner as to make tight joints along the seam ridges.

TABLE OF SIZES, WEIGHTS, ETC., OF TIN SHEETS.

Mark.	Number of Sheets in Box.	Dimensions.		Weight of Box.
		Length.	Breadth.	
		Ins.	Ins.	Lbs.
IC, . . .	225	13¾	10	112
IIC, . .	225	13¼	9¾	105
IIIC, . . .	225	12¾	9½	98
IX, . .	225	13¾	10	140
IXX, . . .	225	13¾	10	161
IXXX, . .	225	13¾	10	182
IXXXX, . .	225	13¾	10	203
DC, . .	100	16¾	12½	105
DX, . . .	100	16¾	12½	126
DXX, . .	100	16¾	12½	147
DXXX, . .	100	16¾	12½	168
DXXXX, .	100	16¾	12½	189
5 DC, . .	200	15	11	168
5 DX, . .	200	15	11	189
5 DXX, . .	200	15	11	210
5 DXXX, .	200	15	11	231
5 DXXXX, .	200	15	11	252
ICW, . .	225	13¾	10	112

A box of 225 sheets, 13¾ × 10, contains 214.84 square feet; but, allowing for seams, it will cover but 150 square feet of roof. To find area of roof covered by any size sheet, deduct 2 inches from its width and 1 inch from its length. A roof covered with tin or other metal should slope not less than 1 inch to a foot.

Leaders.—Leaders should be as large in diameter as they can well be made, so as to insure carrying off the rain or melted snow as fast as may be demanded. If small, they are not only apt to carry off the rain too slowly, but to become clogged with leaves or other obstructions, and in freezing weather to become full of ice, which causes bursting and leakage and general disfigurement or damage. For preventing this, the most sensible pipe has lengthwise corrugations, preventing its bursting by permitting it to "give" with the expansion of the frozen water, so as not to cause any rupture of the pipe itself. The leaders should have ample connection at the ground, and the tops should be covered with a basket of wire, to keep out leaves, pieces of paper, etc.

Skylights.—If there is any one operation that does require light it is that of cleaning grain; but we often find cleaning machinery in an attic, requiring the aid of a lamp or candle, with its attendant dangers, to see what is going on. To prevent this, skylights, which afford perfect protection from the weather, while giving all the light required for this primary operation in milling, may be used.

Ventilation.—No building in which human beings pass their time should be without means of change of air. In flour mills, no matter how carefully the machines are cased in, there is a great quantity of fine flour dust

floating around, and this is breathed in each minute by those in the mill. If there is some means of changing the air, the quantity of this fine dust is materially lessened and the effect on the lungs is less injurious. "Although carefully prepared statistics show that lung troubles resulting from working in a dusty atmosphere are not so prevalent among millers as in many other similar occupations, yet the influence of mill dust upon the health of the miller is of enough importance to demand attention. The sunbeams in a darkened room reveal the large amount of dust which is imperceptibly inhaled, even under ordinary circumstances, in the common living-room of a dwelling. How much greater is the quantity found in a mill or factory, where every nook, corner, sill, and rafter is saturated, so to speak, with the finest, almost impalpable, dust, which the slightest jar or breeze whiffs into the nostrils of the workman. Beside the mechanical irritation occasioned by these particles, detrimental effects result from their decay, and chronic impairment of health often ensues from dust thus inhaled. The constant exposure of millers to mill dust enfeebles the air vessels and often leads to deposits, which become a serious embarrassment later in life. Evidence of their vocation is frequently found in their lungs; and it is asserted that many a man can have his occupation thus determined long after he has retired from the trade of his early or middle life. A physician relates that the proprietor of a drug mill, whom he attended, who had left his work ten years before, still showed in his sputa the marks of his business. Various forms of respirators, designed to be worn over the nose or mouth, have been devised for the protection of dust-workers. Users of grindstones and emery wheels in large factories are compelled to use something of this nature. Sometimes a porous sponge is employed; at others, an artificial hair moustache is used. The habit of thoroughly washing out the mouth and nostrils at noon and night, if not oftener, is urged upon workmen thus exposed. While at work, the miller should keep the mouth shut and breathe wholly through the nostrils. The hairy or ciliary provision in the nostrils keeps much of the dust from going into the lungs, and a hairy upper lip is not without advantage in this respect. Dust-workers are reminded that the lungs perform a function no less vital than that of the stomach. Their structure being more delicate than that of the stomach, the access to the blood and to the life is more direct. It, therefore, behooves the miller to endeavor not to absorb any more of the disturbing element into his lungs than the greatest care consistent with his occupation will permit, and to adopt such simple measures for protection as above suggested." There are many systems of ventilation employed, and many which do not ventilate at all. It must be borne in mind that a system that will ventilate well in summer is apt to totally fail in winter, because the conditions are very different. Ventilation by keeping the air uniformly dry aids very much the action of the bolts.

Lightning Rods.—With the advances in practical science, much of the mystery and uncertainty attending the use of lightning rods have been done away with, so that now they are indispensable to almost every building, and when properly applied are a good protection thereto. Lightning rods are especially desirable on a flour mill, where the air is likely to be filled with

flying dust, and hence explosive or at least inflammable by any spark of fire. There are a great number of rods in the market, varying in composition, construction and modes of joining. The makers of each one try to persuade property holders that in their rod, only, lies complete safety from lightning stroke. As a general principle it may be laid down that any system of metallic connection between the large reservoirs of water below the first stratum of the earth will, if properly accompanied by a system of points above the roof line, give immunity from lightning. A metal roof connecting with the water leaders, which in turn connect with the iron water or gas mains, constitutes, when these surfaces are well wetted by the rain accompanying a thunder storm, a perfect protection,—requiring only that these rods should be properly connected, based, and pointed. A rod is said to protect a radius about it equal to double its height; thus a rod projecting ten feet above the roof will protect a circle of forty feet diameter. Sections of the rod should be put together by brazing, by riveting, or by well fitting screwed joints. There is no use in having a good rod, well placed and well pointed, unless the ground connection is perfect. This cannot be too strongly insisted upon. The greater the cross section and exterior surface of a rod, the greater its conducting and protecting powers.

The late Professor John Wise, an eminent balloonist, but no electrician, collected statistics of many buildings, with rods, that were struck by lightning. He gave his own opinion on this subject before the section of meteorology of the Franklin Institute, and he had the subject of his own remarks published in the daily papers. His erroneous views never received even the shadow of indorsement from the Institute; but they led to the appointment of a committee to report on "The visible effects of and damage by lightning, and the feasibility of certain protection of property and life." This committee was composed of the following named members: J. B. Burleigh, LL.D., electrician and author, chairman; Charles M. Cresson, M. D., physicist and expert; William H. Wahl, Ph. D., formerly secretary of the Institute, and an eminent scientist; David Brooks, inventor and telegraphic expert; Robert Grimshaw, Ph. D., author and scientific expert. It has just completed with great care a voluminous report. The research, extended statistics and scientific reliability of this report, should render it the authority needed by every one who has property to protect and desires to do it so as to secure perfect safety. The following extract is in advance of its publication:

"The science of lightning conductors for the safe protection of property and life should keep pace with the science of architecture. The modern improvements and progressive changes in the construction of buildings, the substitution of metal for wood, the introduction of good conductors into a building, the metal water and gas pipes render a plan of protection that would have been safe in the days of Franklin totally unsafe at the present period. This is one cause why lightning rods occasionally fail. Another cause is ignorance, or the desire to save labor in not digging an excavation or well down to permanent moisture, and then omitting to put a ground plate or an abundance of scrap metal to aid the rod in securing equilibrium by the upward movement, in the rod, of the opposite terrestrial electricity.

For the rod conducts the upward movement of electricity the same as a green tree in the spring conducts the upward movement of sap. Again, neglecting to make a complete circuit with the lightning rod and arranging it so that not even a single point can be struck without having at least two outlets for the opposite electricities to unite and secure equilibrium, is the cause of an occasional failure. Sometimes well meaning persons start in the lightning rod business; they imitate past workmanship, put up several of the best solid platina-tipped points, have but one run down, and save rod by using only a foot or two in dry earth, or nearly dry earth. Then they marvel because the lightning leaves the rod and sets the building on fire. When the definite latent laws of electricity are complied with the lightning rod never fails. As there is a definite and wonderful law in perpetual action, between evaporation and the fall of rain or snow, to make the annual equilibrium of moisture about the same; so a similar definite but transcendently more marvelous action pertains to the equilibrium of the invisible but all powerful terrestrial and atmospheric forces of nature. Electric neutralization is maintained by the conductivity of the entire vegetable kingdom. Hence the supreme metallic conductor of suitable size, scientifically erected and kept in repair, secures certain safety from all damage by lightning to the building and its occupants. The perfect lightning rod insures safety from lightning as the perfect roof insures security from rain. In 1822 the French government applied to the Academy of Sciences for the most perfect system of lightning rods. After a series of meetings and the most careful deliberation a report was made by this most eminent body of scientific men in the world. The French government immediately issued an order to have all of the public buildings throughout the empire protected against lightning according to the plan recommended. A committee from the same body of eminent philosophers reported again at the request of the government, in 1854, in 1855, and finally in 1867. The result of all of their examinations and deliberations was, that lightning rods of sufficient size (copper, $\frac{5}{8}$-inch, or galvanized iron, $\frac{7}{8}$-inch), properly made, scientifically erected, connected with the subterranean water bed, and kept in repair, are always a certain and infallible protection against lightning."

There are many forms and variations of rod section and of connections. Some of these are got up merely to suit the whims of the seller or purchaser. Some of them are founded upon correct, and some upon doubtful scientific principles; and some, while said to possess superior virtues over their fellows, are, in fact, not so good.

The materials employed are galvanized wrought iron and copper. Of these two, the latter is the best conducting material. In section they are best star-shaped and solid. These are only the more simple forms. There are many combinations which there is no room to present here. From the catalogue of Reyburn, Hunter & Co. (North American Lightning Rod Company, 494 St. John street, Philadelphia), we select for mention some of the many styles. We believe that this firm is the largest manufacturer of lightning rods and attachments in the United States, if not in the world.

Galvanized rods, star-shaped, should be connected with copper socket

couplings in which a female screw engages with corresponding male screws on the ends of the sections of rod. The patent star, galvanized rod, $\frac{5}{8}$-inch diameter, is large enough for ordinary buildings, and is the size generally used. A $\frac{7}{8}$-inch rod of this style is used for chimneys, stables, and large, high buildings. These rods should be galvanized with the best Silesian spelter, in order to preserve a bright surface. Galvanizing is necessary to prevent corrosion and consequent loss of conductivity. The patent star copper section is made of wrought iron, also galvanized, and covered with sheet copper, and then both are twisted. The Phelps patent cable is composed of a centre or core of four copper wires twisted together and surrounded by six galvanized iron wires. One variation of it substitutes galvanized iron wire for the centre. The Cushman patent cable consists of four No. 8 galvanized iron wires and four copper wires, all twisted together. Another form is made by placing five wires, plain or galvanized, round a large centre wire and covering all with sheet copper—the cable being twisted into star shape. In the Munn patent cable, four iron wires are covered with sheet copper, the whole being twisted, drawing the two edges of the copper wire between the wires. The copper wire cable rod is composed of twenty-eight strands of copper wire, or of four No. 9 and four No. 16, or seven large wires. Cables are continuous; hence there is no risk from imperfect fittings. The vertical points should be held up by three-legged galvanized braces. The $\frac{5}{8}$-inch solid copper star rod is an excellent and durable conductor.

Paints.—The principal materials used in painting about mills are oxides of metals, ground in raw or boiled linseed oil, and silicious paints, which are either oxides ground in silicate of potash (water glass), or silica ground in oil. The leads, ground in oil, are generally sold in kegs of 25, 50 and 100 pounds' capacity, requiring to be thinned before using. The thinning mediums most generally employed are linseed oil and turpentine. Linseed oil is used either raw (unboiled), or boiled. When raw oil is used, driers are a necessity. The best driers are powdered litharge, Japan varnish, sugar of lead, sulphate of zinc, and turpentine. Turpentine is not, strictly speaking, a drier, but by its rapid evaporation causes the paint to harden more rapidly.* Japan varnish and litharge are the most common. To every ten pounds of keg paint half a fluid ounce of varnish or half an ounce of litharge is added. Care should be taken in employing varnish as a drier not to use more than

*Oil or spirit of turpentine is generally supposed to be a drier, and is used as such, while in fact it is only a thinner and has no drying properties in itself. This has been repeatedly proved in various ways, but the following simple experiment will suffice: In two vessels of equal size and shape put equal quantities of linseed oil, and with one mix a quantity of turpentine. Allow both to be exposed to the same atmospheric influences and watch them. Very soon you will find the quantity in each vessel to be alike, showing that the turpentine has entirely evaporated; after which, if you can perceive any difference in the rapidity of the drying between the two, it will be in favor of what was originally the pure oil. When a mixture of linseed oil and spirit of turpentine is spread out over a surface, the effect is produced which has led so many to call turpentine a drier. The turpentine rapidly flies off, and the oil is left in a much thinner body than if it had been applied pure, and the air has so much the better chance to operate on it, but the turpentine has left nothing behind to aid the hardening or drying process. Painters like to use it because it makes the paint flow more readily, work easier and spread out better. For inside work it is desirable, because as the rule the object is to apply to the surface covered as little oil in proportion to the pigment used, as possible, while for outside work the reverse is the case. Turpentine and benzine are almost identical in their mode of action, the benzine being the more volatile and escaping more quickly. Neither should be used for the outside of a house; but for the inside they answer not only the purpose spoken of above, but, as they evaporate, a "flat" surface, as it is technically called, is formed, and this is generally more highly esteemed.

stated, as it makes the paint brittle and causes cracks. No drier is necessary if boiled oil is used, as in the process of boiling from one to one and one-half pounds of litharge are added. The oil should be boiled for about an hour and a half, stirring the while, to prevent the litharge from settling. Turpentine is a good medium for thinning, as, while causing the paint to flow well and cover evenly, it assists in drying. It decreases discoloration in closed rooms, is less costly than oil, and when used in the last coat produces a dead surface which is very pleasing. As it lacks firmness, it is not so good for outside work as paint thinned with boiled oil. To make a good job of painting, the work should be free from dust and dirt; all knots should be treated to a coat or two of shellac or of white lead, mixed with glue size, to prevent their showing through, &c. Holes and irregularities of surface should not be puttied until after the first coat, as the unpainted wood absorbs the oil, causing the putty to shrink and fall out. Inside work requires from three to four coats, and outside from four to six. Ten pounds of keg paint thinned with three or four pints of oil will cover twenty square yards of first coat, thirty square yards of second coat, forty square yards of third, fourth or fifth coats, &c. Brushes should be cleaned with turpentine and oil if they are to be put away —or allowed to stand in water if they will be in demand in a day or so. For painting metals the best paints are oxides of iron, red and yellow ochres, and red lead, and for galvanized iron (so called) Spanish brown.

Fire-Proof Construction.—There are three principles on which we rely for protection from fire: 1. Careful attention to the use of lights and disposition of fire-generating materials, such as matches, etc.; 2. Suitable extinguishers and well organized fire departments; 3. Fire-proof construction; or, in other words, (1) Care, (2) Extinguishment, (3) Prevention. Fire-proof construction has for some time claimed the attention of architects and builders. With such examples of the inefficiency of fire departments as we have seen in the great fires of the last ten years, the natural stimulus has been toward a protection which would not allow a fire to reach such dimensions with so little warning. To accomplish this desired result various cements and mixtures of different kinds have been tried as filling between walls, floors, etc.; but being found insufficient, a more thorough protective medium was searched for. Finally the hollow brick was adopted as that which most nearly filled the requirements. Bricks are, in themselves, very good building material—their walls remaining intact under great heat long after iron buildings have fallen in misshapen molten masses, or granite has been split, cracked and reduced to splinters. If now this non-conductive material is made hollow, inclosing a volume of air, its non-conductibility is greatly increased. Hollow bricks now on the market are made either of the ordinary brick clay or of terra cotta, fire brick, such as is used in stove lining, concrete blocks made of hydraulic lime of Teil, mixtures of plaster of paris and ashes, etc. Plaster of paris mixtures are objectionable from their liability to crumble with great heat. Clays of different kinds, and concrete, are found to answer best, having a high melting point; besides which they do not readily crumble or crack. Where buildings are constructed with fire-

proof walls, floors, etc., every room is in itself a miniature fire-proof building. In the use of iron for beams, girders, etc., they should be protected in every case, as far as possible, with non-conductive material. Hollow bricks are made in various sections. They are made with edges of different angles, so that a number of them put together will form an arch, which may be either flat or segmental, depending on the sections used. They are much lighter than the ordinary brick—a point of merit in their use for fire-proof flooring. The difference in weight between a solid brick floor and one of hollow fire-proof bricks is largely in favor of the latter.* Where a floor has to sustain a load it is necessary that it be as light as possible with the required capacity for resisting strain. Arches may be made either altogether of hollow bricks or in part, just as required. In cases of hybrid arches, the province of hollow bricks is that of lessening the load. Where segmental arches are used in flooring, the floor is built tangent to the crown of the arch. If a segmental ceiling to the rooms immediately below is undesirable, a false ceiling of hollow bricks is built on angle iron bars forming chords to the span, these being placed eighteen inches apart and fastened by iron clamps to the lower flanges of the girders. In flat arches the sections are such that the joints radiate from a centre, as do segmental arches. The masonry in these arches extends in every case below the flange of the iron beams on which they rest. This extension is carefully covered with cement, leaving no exposed joint which flame might attack. The *voussoirs* and skewbacks correspond in section to the beams on which they rest. Mansard roofs may be built of hollow bricks without being the eyesore to the insurance companies that they are when built in the ordinary way. Partitions built of hollow brick are much less expensive than other fire-proof partitions, doing away entirely with lath, plaster and furring. Iron, encased in, say, two and a half inches of fire-resisting material, is secure. In the form of sectional pipe, hollow bricks are employed as a covering for iron columns, tubular beams, etc. The fire-proof covering is held to the columns by countersunk plates. They are also used as a casing for girders, hollow blocks being cemented together for this purpose. To sum up. The advantages of hollow bricks are these: Rooms with hollow brick partitions are warmer in winter and cooler in summer than those having partitions made in the ordinary way. Floors, partitions, walls, etc., being composed of non-conductive material, and this heat-resisting quality further augmented by inclosed volumes of air, are less liable to destruction by fire than built of solid materials. They save expense by doing away with furring, lath and plaster in partitions, and concrete filling between floors; they thoroughly and effectively inclose in a protective medium the iron work used in construction; they divide the building into fire-proof compartments, thus largely limiting the spread of a fire; they produce the general desired result of fire-proofing at a much smaller cost than arrived at by any other known method.

The loss by fire in the Yeager mill, in St. Louis, was four hundred and nine thousand three hundred and fifty dollars ($409,350). This mill was

* See table on weight of floors.

supposed to be fire-proof; but the system of building and protecting was very defective.

In the new Washburn A mill at Minneapolis, there are upon each floor, coiled up for instant use, properly attached to six-inch stand pipes that pass up through all the floors at both ends of the building, about one hundred feet of rubber hose with nozzles affixed. These are supplemented on each floor by numerous chemical extinguishers and barrels of water over which are hung red buckets, properly marked and always in place. There is also a chemical engine standing in the building. By a system of electric bells and speaking tubes any floor can be brought into instant communication with any other in the vast building.

Fires and Their Causes.—According to the fire tables of the *Insurance Chronicle* for the five years ended with 1879, there was reported a total of 1,346 flour and grist mills, grain elevators, grain warehouses and feed stores burned in the United States and Canada. We place the whole together, that the flour and grain risk may be seen at a glance. This number made 5½ per cent. of the whole number of destructive fires reported. For the year, 1879, of flour mills 181 were reported. Of this number, 21 burned in January, 24 in February, 14 in March, 13 in April, 15 in May, 12 in June, 13 in July, 13 in August, 12 in September, 9 in October, 25 in November, and 10 in December. Of grist mills, 96 were reported burned, as follows: 12 in January, 4 in February, 9 in March, 13 in April, 7 in May, 8 in June, 6 in July, 6 in August, 6 in September, 10 in October, 12 in November, 3 in December. In the year, 1878, 128 flour mills were reported burned in the United States and Canada; in 1877, 102; in 1876, 87; in 1875, 88. In 1878, 94 grist mills were reported burned; in 1877, 46; in 1876, 38; in 1875, 29. It will be seen that, according to the tables given above, destructive fires in mills have steadily increased during the last five years; but this increase is probably only apparent. The number of mills has been largely augmented in that time, and a greater percentage of fires that occur is reported each year, owing to the increased facilities for gathering news.

As a rule, even in the most modern mills, no provision is made for clearing the space between the elevator pulley and the cross or strut board, except by taking off, by means of a screw-driver, the entire side of the head; and this, of course, is seldom or never done, unless the belt has parted and it is necessary to remove the head to readjust the belt. Many heads are so constructed that enough can be easily removed for any adjustment of the belt without exposing the space under the pulley at all. In such cases, no examination of the fire trap is ever made, and, unless Providence intervenes, at some time the mill will probably go up in smoke, nobody knowing how.

Spontaneous combustion is a cause of many mysterious fires in mills and other manufacturing establishments. The peculiarity of fires from such sources is, that the exact source cannot be determined; so that the same accident or a similar one is liable to happen at a later time. The dripping of oil from a hanger or an over-heated bearing is ordinarily looked upon as somewhat of a nuisance and possibly a slight waste; but it may also be a

most dangerous cause of fire. In discussing spontaneous combustion no account is to be taken of explosion of mixtures of finely pulverized substances and air, such as coal dust, flour and bran, and wool in a state of fine division, etc., but of such substances as have the property of appropriating the elements of heat, and storing them, until sufficient temperature is reached to ignite the mass. Among such substances are cotton and woolen oil wastes, silk, charcoal, lampblack, coal, hay, etc. The spontaneous combustibility of bodies may be referred to three sets of causes: 1. By spontaneous explosion of highly combustible mixtures, as gunpowder, nitro-glycerine, etc. 2. By direct chemical action, as the combustion of metallic potassium on the coming in contact with water. 3. By "eremacausis," or slow combustion, as the rotting of a log or ignition of cotton waste. The causes of the effects termed spontaneous combustion come under the last two heads. The fact that waste (either cotton or wool), saturated with oil, is liable under favorable, and frequently occurring, circumstances to spontaneous ignition, is too well established to require any proof. How many times do we read of the destruction of cotton mills and machine shops by fire, and "the cause of the fire unknown." In such cases the chances are very largely in favor of the cause's being that waste soaked with oil or turpentine or varnish has been left exposed to the action of the atmosphere, and by the oxidation of the oil has stored up sufficient heat for self-ignition, and as a consequence fired the building. It has been proved that moisture is very favorable to oxidation, increasing the rapidity; therefore, if the waste is kept dry it is in diminished danger of ignition. Other things being equal, mineral oils are less liable to spontaneous combustion than animal or vegetable; non-drying than drying; heavy than light, the reason being, in the latter case, that the flashing points and burning points of heavy oils are much higher than light. Silks have been known to spontaneously ignite. The late Professor Wise, in his "Through the Air," states that he lost several balloons through this property. In these examples, doubtless, the varnish was the chief cause. Charcoal and lampblack are both very susceptible to spontaneous combustion. Both possess the property of absorbing and retaining gases to a wonderful degree. The oxygen is appropriated from the atmosphere and stored within the porous mass until a sufficient quantity has been condensed to raise the carbon to incandescence. In this absorption of oxygen from the atmosphere, a species of natural selection seems to be exerted, by which the nitrogen is refused and the oxygen appropriated. As before stated, spontaneous combustion is greatly aided by moisture, and in some cases no ignition can be brought about without its presence. A drop of moisture on a window pane is often sufficient to cause an explosion in a lampblack mill. If a drop of perspiration or of water falls in a pile of lampblack the moistened portion is instantly carried out of the building, for that spot would begin to heat and continue until ignition took place, and the little incandescent nucleus would gradually extend until the whole place would be on fire. The cause of spontaneous combustion of coal has not been so definitely established. It is thought by some to be the oxidation and decomposition of iron pyrites, the heat thus produced firing the mass. This will not, however, account for all the cases

of spontaneous combustion of this article, as coal free from pyrites is quite as liable to ignite as "brassy" coal. The real cause is probably the same as in the case of charcoal and lampblack, *i. e.*, occlusion of oxygen within its pores. In the year 1874, 4 per cent. of all vessels carrying coal were destroyed by the spontaneous combustion of their cargoes. The prevention of this has been attempted by the expulsion of air from the hold and bunkers by means of carbonic acid gas. Farmers are aware of the charring of the interior of a haystack when the hay is not properly cured. All cereals are supporters of animal parasitic life. These parasites breathe oxygen or give off carbonic acid. They thus form mediums for the storing of oxygen. Vegetable parasites absorb oxygen in their pores; and both animal and vegetable are liable to ferment. If the hay be stacked wet, by a process of budding these parasites increase enormously—constantly increasing the supply of oxygen and causing the mass to heat until the interior is charred or the whole consumed. If, on the other hand, the hay is thoroughly cured by spreading in the sun until the juices of the plant are dried up and all parasitic life destroyed, its liability to spontaneous combustion is reduced to a minimum. A little pile of middlings, on which oil drops from a bearing, will soon heat and burn.

Middlings and oil are not alone in their power of generating fire. Damp smut or bran will do it. One mill has been told of where fire was caused by dampness in the smut room, and another where a bin of bran which had been used a long time without having been entirely cleared out gathered dampness at the bottom, from which combustion ensued. One mill may run for years without any accident without taking any precaution. If it escapes, it is only because the atmospheric conditions of an explosion are not fulfilled, "more by good luck," etc. Elements of destruction are ever present.

There are few mills where there is sufficient precaution taken against sudden explosions and fires; and sometimes millers are more than ordinarily careless. There is one case on record where there was a grist of very dry buckwheat being ground at night and run through a muslin bolt kept for coarse grain; some black specks in the flour showing a defect in the cloth, one of the doors was opened to learn the reason, when the bolt was in motion. On taking the candle near the door there was an explosion: both dust and silk vanished in a flash, leaving nothing but the bare skeleton of the reel.

Soft coal is peculiarly liable to spontaneous combustion, especially fine coal or culm. If stored, when the least wet or damp, in closed sheds or where there is little or no circulation of air, this danger is increased. There is an additional reason for protecting coal from wet; and that is that it will lose much of its heating power if not kept dry, beside emitting gases which are noxious to the throat and lungs. A recent circular of the Manufacturers' Mutual Insurance Company calls attention to the property which most bituminous or soft coals—and some semi-bituminous varieties—possess of taking fire spontaneously when exposed to moisture, or even dampness, in a place without free circulation of air. Aside from the danger of fire, the same

causes which, when acting strongly, cause spontaneous combustion, are likely, when present in a less degree, to give rise to injurious vapors of sulphurous acid, carbonic oxide, and other products. Even with anthracite coal, a suffocating effluvium, perhaps of sulphurous acid, is often perceived when the contents of the bin are disturbed.

Artesian Wells.—These are of use in places such as we often find in cities where the supply of water in case of fire is drawn from the city mains, and is liable to fail in case there is another fire in the neighborhood, and the steam fire engines draw from the mains. It would not be very pleasant to be left without water in such a case, especially if the roof was of wood and the wind in the direction of the mill. In this case an artesian well comes in play.

Tanks.—Tanks for water are best made of cedar wood or of iron, the latter either painted or galvanized. Where there is to be a tank of any considerable size provision must be made for its support, as water is a very heavy article. Many buildings have been badly sagged out of shape by a large water tank. A cubic foot of water weighs about $62\frac{1}{2}$ pounds; a gallon about 8 pounds. The subjoined table gives the contents of tanks, of different diameters, in cubic feet and in United States gallons of 231 cubic inches (or 7.4805 gallons to a cubic foot) and for one foot of height of the tank. With the figures given the contents of a cylindrical tank, of any height and of the various diameters stated, can be found. For tanks of any given height multiply the figures given below by the height of the tank in feet. Thus, a tank 48 inches in diameter and 5 feet high will contain 62.830 cubic feet, or 470 legal United States gallons of 231 cubic inches to the gallon. For the weight of water multiply the number of cubic feet by $62\frac{1}{4}$, which will give it roughly.

Inches Diameter.	Cubic Feet.	Gallons of 231 Cubic Inches.	Inches Diameter.	Cubic Feet.	Gallons of 231 Cubic Inches.
24	3.142	25.00	54	16.904	118.94
27	3.976	29.74	60	19.036	146.88
30	4.909	36.72	66	23.760	177.72
33	5.940	44.43	72	28.276	271.52
36	7.069	52.88	78	33.184	248.24
39	8.296	62.06	84	38.484	287.88
42	9.621	71.97	90	44.180	330.48
45	11.045	82.62	96	50.264	376.00
48	12.566	94.00			

Pumps.—For fire protection a pump should be put in that can be forced to a high capacity and run, without stopping, for a long time. It must be remembered that the fire pump of a mill is not always used to put out fire in the mill itself, but to protect neighboring buildings, and perhaps a whole district.

Every year the hydrants should be carefully looked after to prevent their freezing in the winter. Rotary pumps should be emptied by turning them back-

wards. All left-hand valves and water gates should be distinctly labeled to prevent their being broken by attempts to turn them the wrong way; as well as to save time in case of fire. Every left-hand valve should be plainly labeled and marked with an arrow to show the direction in which it should be opened; it is better to remove them entirely and replace them with right-handed valves.

Hose.—Sufficient hose should be provided to meet all possible requirements. All hose should be inspected and tested under fire-pressure at least once every three months; and it would be better if it was looked to each month. The fire hose should never be detached from the stand pipe, and never loaned for any trivial purpose. Only first-class hose should be purchased. That from the New York Belting and Packing Company, 37 Park Row, New York, may be recommended. This company manufactures an antiseptic test hose which is made under a patented process for preserving the hose from mildew or rot. The duck used in the manufacture of this hose is made from the very best long staple cotton, making a duck of the greatest tensile strength possible to be made. All of the duck used in the manufacture of this hose is chemically treated with carbolic acid, supplied directly to the duck at a temperature of over 300 degrees of heat, which is the only process whereby the fungi or decomposing matter in the duck is effectually destroyed. The rubber used in the manufacture of this hose is all fine Para, being the strongest and very best rubber known. The ends are made extra heavy to resist the greater pressure they are subjected to, and capped to prevent air or dampness penetrating the hose. The rubber suction hose is made on spiral brass wire, in sizes from $\frac{3}{4}$ inch up to 2 inches internal diameter, and on flat galvanized iron wound spirally in sizes from $2\frac{1}{2}$ inches up to 12 inches. The "smooth bore" suction hose has metal imbedded in the rubber, entirely out of sight, so that the interior or bore is perfectly smooth. The company also manufactures all other kinds of hose, such as "conducting," for leading water under moderate pressure; "hydrant," suitable for hydrants, force pumps, etc.; "engine," for all general purposes where a strong, reliable hose is required; "extra heavy steam" and "star linen" and "cable" seamless multiple cotton hose. The "star" and "cable"

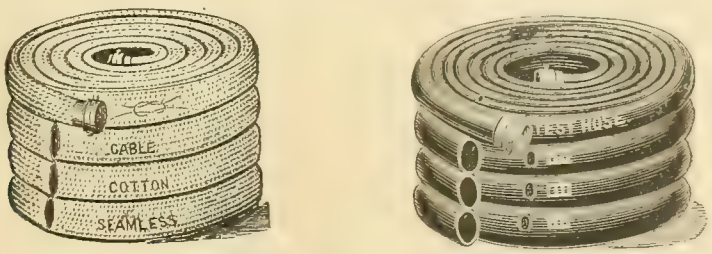


FIG. 1.—NEW YORK BELTING AND PACKING COMPANY HOSE.

are rubber lined, and all of the fabric hose is prepared under the antiseptic process.

The Hydraulic Ram.—Where economy of water consumption is not considered, hydraulic rams have probably no equal in cheapness of work and thoroughness of action. Simplicity, automatism, convenience and low

price are some of their principal features. For supplying country houses, barns, factories, mills, and railway stations, they are much cheaper than pumps doing the same work. As ordinarily made, they are capable of pumping from half a gallon to eighty gallons per minute, and discharging it at a distance up to 150 feet. All that is necessary is plenty of water, with a fall of not less than 18 inches, with a drive of not less than 25 feet. This length of pipe is necessary to accumulate the required pressure and velocity of supply. If space is limited, this length of pipe may be obtained by coiling the drive in, say, a six-feet coil. This gives the necessary ramming pressure and velocity, and economizes space, as the coil may be placed directly under the flume. The drive pipe should be as free as possible from elbows or short turns, as these cause friction and loss of power. It should also be placed underground to be out of danger from frost and external injury. The power of hydraulic rams is directly proportional to the height of the falls; and the height to which the water is raised to the height of the falls. With a fall of 5 feet, water can be raised to a height of 50 feet; and with a fall of 10 feet to a vertical or horizontal distance of 150 feet. The ratio existing between the water used and the water wasted ranges from 1 : 10 to 1 : 14; or in other words from 1-10 to 1-14 of the water supplied by the drive is utilized, while the remainder is wasted. This may seem wasteful for the amount of work done; but, when it is calculated what would be the cost to accomplish the same work by another machine, such as a wind mill, it will be found to compare very favorably with it, or any other machinery, to accomplish this same work. It is true that a wind mill requires little or no attention, but it is also true that it will work only when the "spirit moves it,"—whereas the ram is always ready for work, and automatic in its action, requiring only that the sluice shall be opened for it, when it will pump until stopped. American hydraulic rams are better than European. A good American hydraulic ram will discharge, at 100 feet vertical and 100 feet horizontal distance, as follows :

Vertical Distance.	Horizontal Distance.	Ram Number.	Gallons per Minute.
100 feet.	100 feet.	2	.12
100 "	100 "	3	.23
100 "	100 "	4	.49
100 "	100 "	5	.86
100 "	100 "	6	1.54
100 "	100 "	7	3.08
100 "	100 "	8	7.06
100 "	100 "	9	15.04

Such rams are made of cast-iron and brass, with brass valves and valve stems; are very durable and inexpensive—a No. 2 costing $9, and a No. 9 $225. The hydraulic ram is really a French invention—Montgolfier, the balloonist, first conceiving the idea. Yet at the Paris Exhibition of 1878,

where American rams were shown in operation, they were viewed with suspicion by Frenchmen, they insisting that there must be a concealed pump to perform the work done.

Chemical Extinguisher.—The chemical extinguisher has, of late years, taken an advanced position as a fire combating agent. It is of great value for the extinction of a fire in closed rooms. It should be frequently tested.

Fixed Water Pipes.—One method of fire extinguishing which is largely employed in New England, among the cotton factories, is the system of fixed water pipes, extending through every story and extending along all the ceilings. This system of pipes is in permanent connection with a powerful force pump, and the ceiling pipes have their sides and underneath portions perforated with fine holes, which makes them act as very thorough sprinklers. Over these holes thin tissue paper should be pasted in order to prevent their clogging with dust. Each story should have its own pipes; and if possible those of each story should be painted of a special color, in order to distinguish it from those of other stories. Each pipe should have its valve properly labeled and numbered, so that when the pump is put in action any desired story may be at once subjected to a thorough drenching, directly the fire signal is given by electric bell, speaking tube, or other alarm. Water pipes should have as few bends as possible, and they must not be run where they are liable to freeze.

Steam Pipes.—Steam is an excellent extinguisher where there is a confined place in which to act. In that case it is a sure suppressor of combustion. The steam extinguishing system costs little to fit up, nothing to maintain when not in use, takes up little space, is always present and quickly available.

Heating.—The method of heating most commonly employed, especially in steam mills, is by steam pipes, either in straight lines or in coils—although these last are frequently superseded in the best and largest mills by radiators made of cast or wrought iron or of short lengths of straight pipe. Heating by steam has the advantage that it is easily controlled, and the disadvantage that unless it is well controlled the temperature is apt to rapidly vary beyond the limits of endurance or at least of comfort. Steam pipes have the advantage that they take up little room. They can be readily put in buildings that were not intended to have them, are less trouble than stoves, and are more readily controlled. The Boston Manufacturers' Mutual Fire Insurance Company recommends overhead heating pipes, because one of the greatest dangers to which they are exposed and one of the heaviest causes of loss are the collection of combustible material on steam pipes where they are ordinarily placed at the sides of the room under the windows. One of the most frequent faults reported by their inspectors is "Combustible matter on steam pipes." There is, aside from insurance considerations, less liability to breakage.

There is no fixed rule which can be laid down about how many square feet of heating surface, or how many pounds' pressure will be needed for each and every building. The kind of building and its location are

important factors in the calculation. Thus, wooden buildings need more pipe or more pressure than stone, and stone more than brick. Those with iron fronts need still more (other things being equal), and those that have the fronts largely in glass take most of all. The number of cubic feet of space heated by one horse-power of steam is approximately as follows:

Brick dwellings, in blocks, as in cities,	20,000	cubic feet.
Brick stores, in blocks, as in cities,	15,000	" "
Brick dwellings, exposed all round,	15,000	" "
Brick mills, shops, factories, etc.,	10,000	" "
Wooden dwellings, exposed,	10,000	" "
Foundries and wooden shops,	8,000	" "
Exhibition buildings, largely glass, etc.,	5,000	" "

Each horse-power of a boiler will supply about 300 feet of 1-inch steam pipe, or 100 square feet of heating surface for direct radiation, and for indirect radiation 420 feet of pipe or 140 square feet of surface. Doubling the diameter renders it necessary to add 30 per cent. to the surface; and, trebling the diameter, 30 per cent. is required.

Lighting.—A liberal allowance of light is desirable in every mill. There are some locations where it is next to impossible to get it without resorting to some special contrivance. When there are neighboring buildings that are very near or very high, inclined reflectors may be used similar to those employed in cities, and which will throw inside of the buildings the light which comes from above. If the faces of the windows are made flush with the outer surface of the wall more light reaches the interior than if, as is generally the case, they are set back a few inches. Sashes should be made preferably of iron, as being more nearly fire-proof than wood; and fire is a thing that almost every mill must look forward to as bound to come sooner or later. The French style of windows, hinged at the side, is well adapted to flour mills, if the sashes open outward, so that in case of explosion they will readily yield to the outward force, and thus save some of the damage to life and property within.*

The methods of artificial lighting are by candles, lamps, fixed illuminating gas, carbureted air and the electric light. The candle is one of the most common sources of fires, and the lamp is about as bad. If lamps are used no oil should be burned that "flashes" at less than 110° F. The gas machine, commonly so called, does not generate illuminating gas, but affords a supply of atmospheric air, saturated to a greater or less degree with hydrocarbon vapor. The difference between vapor and gas is that the gas is in a permanently gaseous condition, while a vapor is only temporarily so and liable to condense again into liquid form with time or lowering of temperature. Still there are many cases where large mills could do better by making their own gas than by buying it from the city or the gas company. The Seneca Lake Mills, Watkins, N. Y., are lighted by the electric light.

* Suggested by Mr. Louis C. Madeira, Philadelphia.

Estimates.—Comparatively few persons appreciate the importance, in asking for estimates, of being explicit, so that manufacturers, millwrights or builders may have a clear understanding as to just what is wanted. For instance, a letter is sent asking for an estimate on "a three-run mill," or "an engine and boiler," or "bottom figures on a turbine wheel," etc. No one could reply intelligently to such inquiries. "A three-run mill" does not say what is wanted, as one three-run mill may cost $2,000 more than another; an engine may be 5 horse-powers, or it may be 100 horse-powers, and turbine wheels are built from ten inches to six feet in diameter. A correct estimate depends upon the size, capacity, make, power, materials, finish, etc.

If, in asking for estimates or ordering machinery, the following rules are observed (as far as is practicable), much correspondence and many misunderstandings may be avoided, and all parties concerned will have a clear conception of just what is wanted:

1. Where an estimate is wanted for a new mill, give--

The number and size of buhrs (or capacity) wanted.
A full description of location, on level ground or side hill; its relation to road, railway and power; where it is most convenient to receive grist work, and where merchant grain.
If a basement is attainable.
Relative position of site to railroads, streets, etc.
Place to receive grain.
Location of water wheels or engine.
If a "merchant" or "custom" mill.
Old or new process, or straight grade.
Whether you will grind grist, or exchange.
Send sketch, with any suggestions you may wish to offer.

2. If you have a building, give—

Size of sills.
Height of basement, if there is one.
Height of each story (measuring from top of floor to top of next floor).
Height of attic in centre and on sides.
Which way the comb of the building runs.
Position of girders in building, with dimensions.
Depth of joists on each floor.
Are joists set on girders or gained in even?
Number of posts through the building, and if possible send sketch with full dimensions.

3. If you expect to use water power, give—

Head and fall, and number of cubic feet per minute.*
Distance from top of headwater to buhr floor of building, or to top of ground.
If you have a turbine, state what make, size, etc., and how it runs (with or against sun), revolutions per minute, etc.
If you want a turbine, give size, and kind, and location.

4. If you want an engine, give—

Diameter of cylinder and length of stroke.
Size of boiler.
Kind of pumps, etc.
Or, if you wish a person consulted to decide as to engine, state what it is to do, or the amount of work it is expected to perform. (In ordering water-wheels observe the same rule.)

5. If you have an engine, give—

Kind of engine; builder.
Diameter of cylinder and length of stroke.
Length of main shaft from centre of bed to end.
If it runs over or under, that is, whether top of band-wheel runs to or from the cylinder.
Diameter and face of fly wheel.
Diameter and face of main band-wheel if the fly wheel is not belted.
Diameter of overhang and length in full detail.
Number of revolutions per minute.
Send sketch with all measurements noted, showing location of the engine with regard to the building; location of well or tank; and show by arrow which way the engine runs.

* See "Measurement of water power."

6. In ordering buhrs, state—

How they are to run (watchwise or reverse).*
What they are to grind.
With or without balance boxes.
Size of eye in runner and bedstone.
If drive irons are wanted.

7. In ordering mill spindles, give—

Distance from face of bedstone to the wood bridgetree on which the step is set.
Diameter of spindle, etc.
Be particular in giving all dimensions.

8. In ordering pulleys or gearing to go on old shafting, give—

Exact size of bore. (If possible always send a wire.)
Size of key seat, or if set screw is wanted.
Name the place to which machinery is to be shipped and, if thought best, by what route. Give name and P. O. address plainly and in full.

Observe the foregoing and always be explicit. Do not fear being too particular. If possible, however, we would advise you to visit the works with which you are treating.

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* Most makers will send buhrs or any machinery running watchwise, if not otherwise ordered.

CHAPTER II.

MILL PLANS.

Roller and Buhr Mills—New Process Buhr Mill—Three-Run Mill—Two-Run Low Grinding Mill—Niagara Falls Mill—Burned Yaeger Mill—Deseronto Mill—Five-Run Buhr Mill—Two-Run Buhr Mill—Mill Office—Seven-Run Mill—Oliver Evans' Mill.

Roller and Buhr Mills.—As regards the building itself, no difference need be made in size or arrangement between a roller and a stone mill. The building for a 450-barrel roller mill may be about 46 by 68 feet on the ground, and four stories high, with a basement. The basement may be 10 feet high, the milling floor 12 or 14 feet, the next two, 16 feet each, for the bolting and the purifying. There may be an attic for the elevator heads and such like. If it is a steam mill, the engine and boiler should be in a separate building. For making 450 barrels of flour per day of 24 hours there will need to be a 200 horse-power engine or turbine. The main driving-shaft should be in the basement, and be a 3 or $3\frac{1}{2}$ inch line, making 300 revolutions per minute. Immediately above this put the platform for the rolls, of which there must be ten pairs. The shafting on the upper floors may be driven either by an upright shaft taking motion from this main line, or by belts,—as may be convenient. On the first floor place ten sets of rolls, five sets of 30-inch under-running stones, and three flour packers. The bran packers may be either on the first floor or in the basement, as may be preferred. The next two floors should be taken up by the bolts and the purifiers, the chests extending up through the two floors, and the purifiers about equally divided. There may be three chests containing eighteen reels, each 18 feet long and 32 inches diameter, and making 22 to 26 revolutions per minute; or these reels may be put in four chests. There will need to be nine purifiers of medium size, say four on the second floor and five on the third. This number of purifiers will handle the largest quantity of middlings that can be made.

The cleaning machinery may consist of one side-shake separator, two brush machines, and a rolling screen. If there is much cockle there will need to be a cockle machine. This takes care of garlic also—a great nuisance in Pennsylvania. The scourer may be omitted, as the brush machine will do the work better and leave the enamel of the bran in a more nearly perfect state. The cleaning should be done in the basement if possible, so that it may be readily inspected from time to time. For this purpose, the basement must be well lighted and dry. The rolling screen

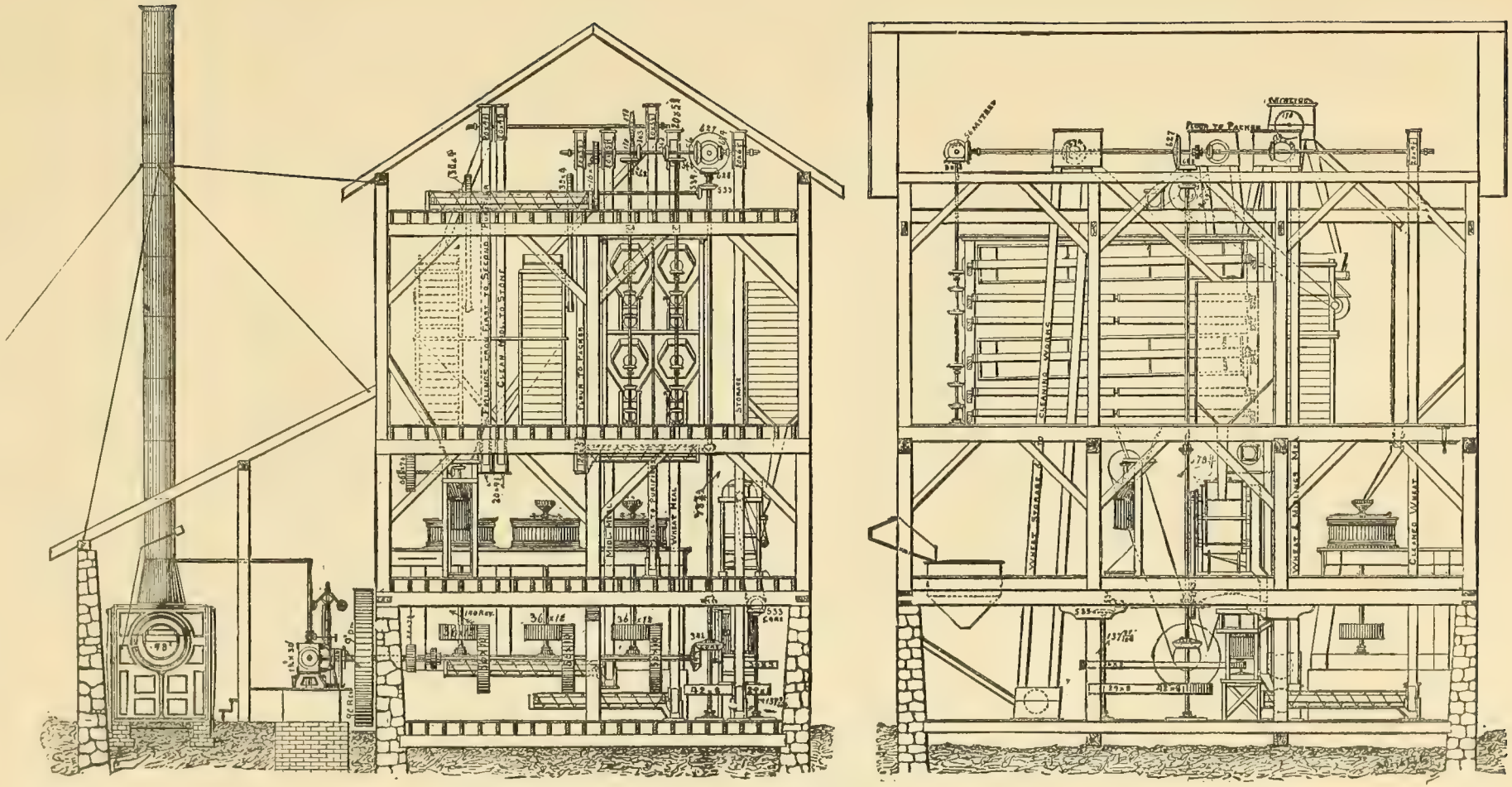
and cockle machine might be placed above, or the material could be run first into the separator, then into the rolling screen, then into the cockle machine, then to the brush, running first down and then up. On the first floor a 1-inch over-head shaft will be required to drive the packers. There should be one line of 3-inch shafting for the bolts, starting at the head, and making 40 revolutions. On the third floor the purifiers should be driven from counters from the 3-inch shaft. This counter shafting should be $2\frac{1}{2}$ inches diameter, and the purifiers will have to be driven, say, 500 revolutions. On the fourth floor put up one line of shafting 2 inches in diameter, driving the elevators. The bran duster may be placed on the second or on the third floor. There should be one heater for each two pairs of rolls. The scalping reels must go in the basement, just under the first floor and under the rolls. These will all be driven from one shaft, 2 inches in diameter, making 20 revolutions. The scratch rolls could either be driven from the horizontal shafts above, or all be geared from the shaft that drives the rolls below. Probably they would be best geared from the roll shaft.

The smallest roller mill that can be profitably put up will be about a 125-barrel mill, with 9 × 18 rolls. A 450-barrel buhr mill should have eleven sets of 4-foot stones, making 160 revolutions, for wheat, and five sets for middlings. These wheat stones would take eight bushels per hour each, and should make about 45 per cent. of middlings.

New Process Buhr Mill (Abernathy).—For a ten-run mill there may be a building 60 by 70 feet on the ground, four stories high, with a basement—this last being at least 12 feet high. The next stories should be respectively 14, 18, 18, 17 feet high in the clear. In the basement at one end there should be the husk frame of iron or wood. Parallel with this, and 16 feet from it, there should be a line of 3 or $3\frac{1}{2}$ inch shafting firmly mounted, running through the outer wall to the motor. From this run reel belts, one for each run of stones, to the stone spindles.

Three-Run Mill.—Figure 2 gives an end and side elevation, and Fig. 3 basement and attic plans, of a three-run mill designed by E. P. Allis & Co., and intended to make from two and a half to three barrels of flour per hour with 36 horse-powers, with an automatic cut-off engine of good construction, and a boiler efficiency of nine pounds of water to one of coal. The consumption of fuel per hour should be 108 pounds of steaming coal, or 0.085 cord of mixed wood.

Two-Run Low Grinding Mill (Allis).—"The driving power of this mill, Figs. 4 and 5, is a 10 × 30 automatic cut-off engine, making 90 revolutions per minute. The power required is about 25 horse-powers, although the engines will easily give 10 horse-powers more. In running the mill for ten hours the fuel required will be about 750 pounds of steam coal or about one-half cord of good wood. Water power can be used to drive this mill in place of the engine where required. The mill consists of two runs of 48-inch old stock French buhr millstones, one used for grinding wheat and the other for grinding corn and feed. The stones are driven by a one-quarter turn belt from the line shaft, and either may be stopped or started without stopping the engine. The stones rest on a wooden hurst frame, and are covered by



End Elevation.

Capacity per hour, 2½ to 3 bbls. of flour.

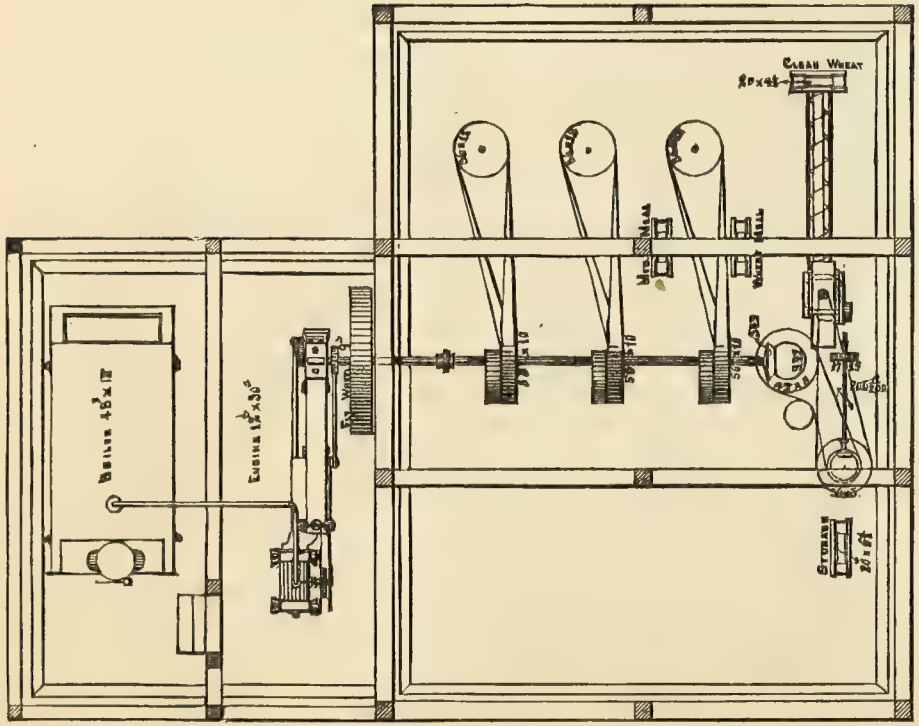
E. P. Allis & Co., Builders.

Fig. 2.—THREE-RUN MILL—Thirty-Six Horse-Power. (Allis.)

Consumption of fuel per hour (Automatic Cut-off engine, high-pressure), 108 lbs. of steam coal, or 0.085 cord of mixed wood.

Side Elevation.

W. D. Gray, Designer.



Basement.

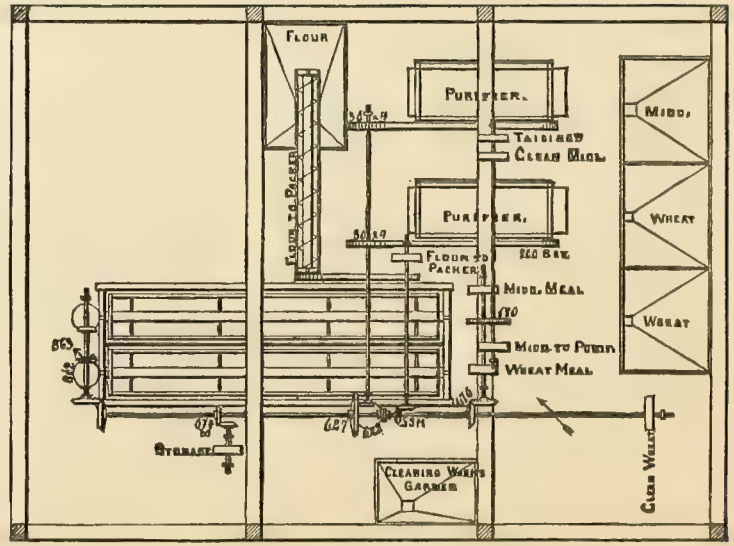


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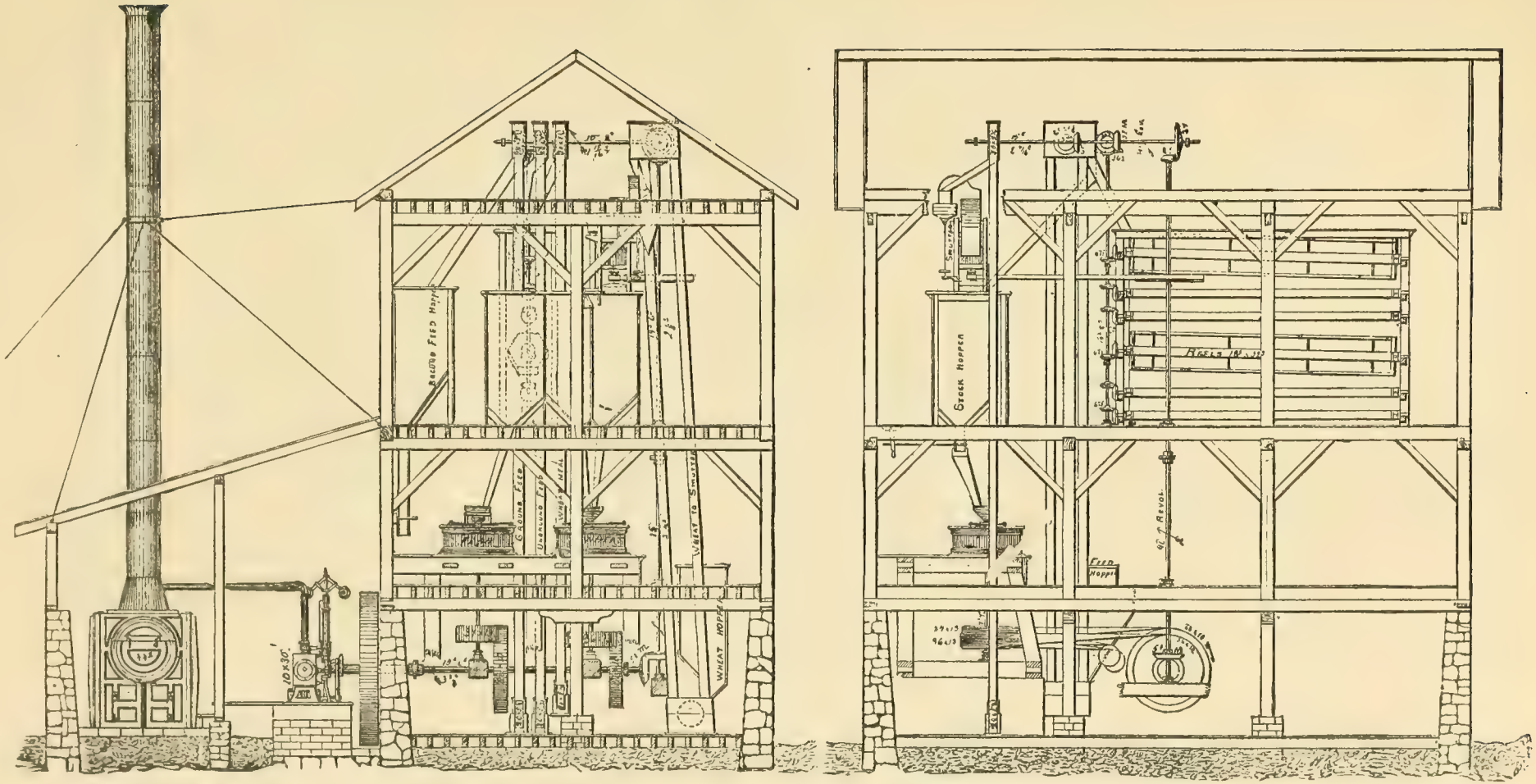
Fig. 3.—THREE-RUN MILL.

E. P. Allis & Co., Builders.

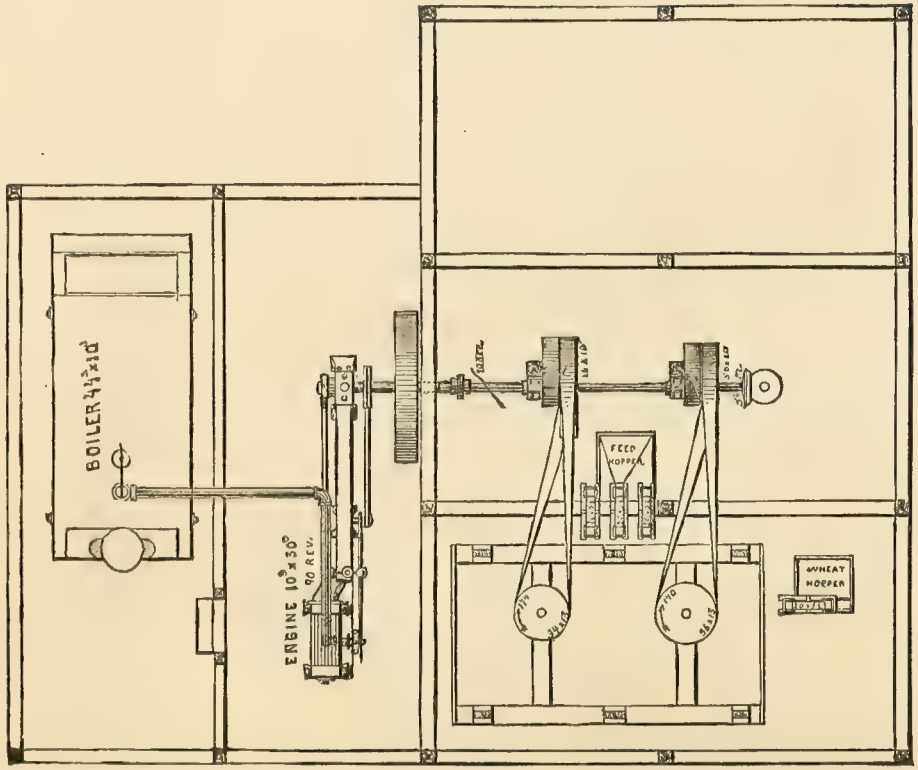
W. D. Gray, Designer.



End Elevation. Fig. 4.—TWO-RUN MILL (Twenty-five Horse-Power). Side Elevation.

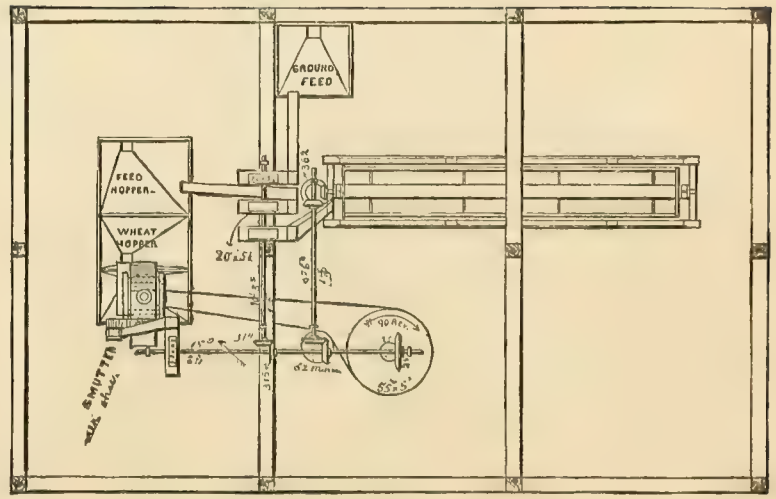
Capacity per hour, 1 to 1¼ bbls. of flour and 25 to 30 bush. of feed. Consumption of fuel per hour (Automatic Cut-off engine, high-pressure), 75 lbs. of steam coal, or 0.056 cord of mixed wood.

E. P. Allis & Co., Builders. W. D. Gray, Designer.



BASEMENT.

FIG. 5.—PLAN OF TWO-RUN MILL.



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walnut finished curbs, the wheat stone having a silent feeder and the feed stone a hopper, shoe and damson. The spindles are of cast-iron, cast on end, and the trampots what are known as copper-lined top lift. The bolts, elevators and smutter are driven from an upright shaft, which is geared to the line shaft in basement by bevel mortise or core gears and pinion with dressed teeth. This shaft rests on a heavy steel step and is supported at each floor by boxes. The main line shaft in the basement is coupled direct to the engine shaft, and is supported on a line of posts by bracket boxes. The smut and separating machine stands on top of the stock hopper on the second floor. The bolting chest stands on the second floor and contains two reels 32 inches in diameter and 18 feet long, with double conveyors under each reel, and is driven by an upright shaft and mitre gear from the line shaft in the attic. There are four elevators in the mill. The wheat is taken in the wheat hopper on the grinding floor and passed into the foot of the wheat elevator, which takes it up into the attic and spouts it into the smut and separating machine, from which it passes direct into the stock hopper over the wheat stone. The meal from the wheat stone is spouted into an elevator and taken to the bolts. The corn or feed is taken into a hopper on the grinding floor and elevated into the stock hopper over the feed stone, and the ground feed is elevated into a feed bin on the second floor, from which it can be drawn at pleasure. With the addition at any time of another one-half chest of bolts, a middlings purifier, a set of porcelain rolls to grind the middlings, and a set of smooth chilled iron rolls for extracting germs, this can be made a high grinding new process mill. The power provided is amply sufficient. A few more elevators would be required and the change could be made very easily."

The Niagara Falls Mill.—Fig. 6 is one of the finest mills in the country, both in point of design and convenience, in the substantial character of the building and machinery, and in the high finish and excellence of the workmanship. The plans were made by E. P. Allis & Co. in the fall of 1877, and in January, 1878, the entire contract was awarded to them. They furnished the entire machinery and superintended the erection of the mill and power, turning it over to the owners, Schoellkopf & Mathews, of Buffalo, N. Y., in September of that year, in complete running order.

The mill and elevator are situated on the brink of that immense cañon, nine miles long, which Niagara has worn out of the solid rock in the lapse of centuries, and whose depth at the mill is 310 feet. The location is something over half a mile from the Falls, and at the end of that expensive canal, only a mile long, which taps Niagara River above the Rapids and Falls. The head race is about 300 feet long, the sides being built of dressed stone laid in cement, and is arched the greater part of its length. There are two head-gates, one at the pond and the other at the bulkhead. This last is made of cut stone and is 18 feet square, and deep enough to hold 15 feet of water. Both raceway and bulkhead were made deep enough to stand over two feet of ice without drawing upon the head. From the bulkhead the water is brought to the water-wheels, a distance of 58 feet, in a tube made of boiler

iron and 10 feet in diameter, the water leaving the tube at right angles with the head race. The pit in which the water-wheels are placed was blasted out of solid rock on the edge of the precipice. It is 50 feet deep, 34 feet wide and extends back 30 feet. The motive power is furnished by two turbines. The pit under the larger wheel is 7 feet deep and 9 feet wide, and that under the smaller wheel is 7 feet deep and 6 feet wide. The penstocks of both wheels are placed on iron girders, supported by heavy iron columns. The larger turbine is 54 inches in diameter, and is placed in an iron penstock. Under a head of 52 feet it gives 660 horse-powers, which is said to be the greatest power furnished by any wheel west of Lowell, and was at that time the greatest power supplied to any flour mill in the world by

FIG. 6.—NIAGARA FALLS MILL.

a single wheel. It is calculated that the power it supplies would drive a forty-run "new process" mill, with all of the necessary machinery. The shaft for the wheel is of steel, and is 53 feet long and 5 inches in diameter. This wheel drives the mill proper and all of its machinery except the flour packers. These and the cleaning machinery, together with the elevator machinery, are driven by a 36-inch turbine in an iron penstock, which, under the same head as the larger wheel, develops about 300 horse-powers. The shaft for this wheel is also of steel, $3\frac{1}{2}$ inches in diameter, and of the same length as the shaft from the larger wheel. Both wheels are regulated by water-wheel governors. The upright shafts of both wheels are carried on wrought iron "I" beams, 36 feet in length, and fastened at either end to heavy cast brackets, which are firmly bolted to the sides of the pit. The driving wheels and line shaft are carried in cast-iron bridgetrees, which are supported by three wrought-iron "I" beams placed across the top of the

pit. It will be seen that everything, except the head gates, connected with the carrying and utilizing of the power is built of iron or stone. We have thus enlarged upon this branch of the subject, not only because it is one of the most interesting points in connection with the mill, but also because it is one of the most expensive applications of water power in the world. The present edifice is only the beginning of a series of manufacturing establish-

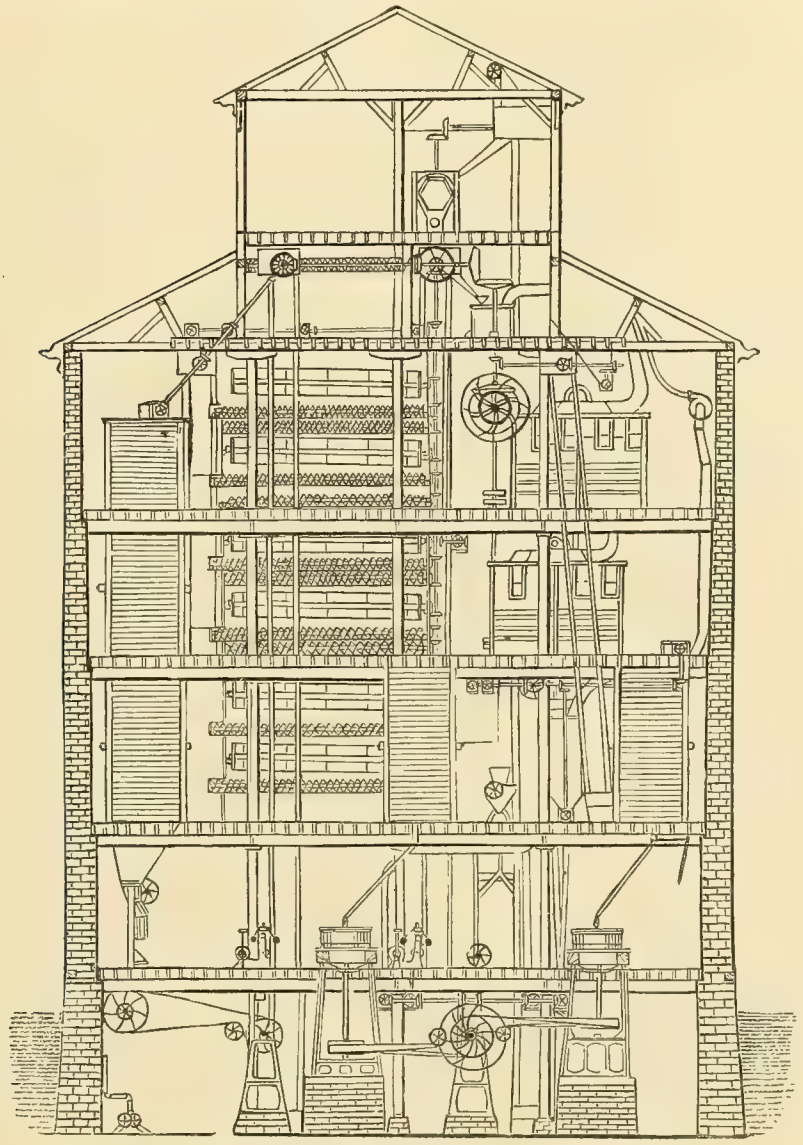


FIG. 7.—SECTIONAL END VIEW OF NIAGARA FALLS MILL.

ments which will make Niagara famous as an industrial centre. The canal, where the power becomes most conveniently serviceable, is only about 200 feet from the river, and there is room right there for thirty mills, each with a hundred feet front, and each driven by a practically unlimited water power. Moreover, this power may be used all the time. In winter the Rapids cause a kind of granulated ice which clogs the wheels of the paper mill at Goat Island. This is not the case with the power supplied to the Niagara Falls Mill. Ice may form in the canal two or three feet thick, and yet an ample supply of water will run under the ice as long as Lake Erie remains where it is.

Let us now glance at the mill building and elevator, accurately represented in the engraving, Fig. 8, but the imposing appearance of which can only be appreciated by actually seeing it and taking in the *ensemble* of the situation. The material used in construction was Niagara limestone, quarried from the basement and wheel pit, and the walls are 4½ feet thick. The main building is 130 feet long, 65 feet wide and 108 feet high. There are six stories, of which the first, third and fifth are 16 feet high; the second, fourth and attic, 14 feet high, and the sixth story, 10 feet high. The roof covering the structure is iron. The mill is planned for thirty-two runs of 4½-foot buhrs, and has at present twenty-two runs in operation. The buhrs stand in two lines of eleven pairs each, the main line shaft running between these lines. The shaft is supported on an adjustable cast-iron stand. The buhrs are driven by quarter-twist belts and are placed on solid iron hursts. On the stone floor there are six flour packers and a very nicely furnished office. A more definite idea of the arrangement of this floor and the other parts of the mill and elevator can be obtained by consulting the sectional views.

The third floor contains six sets of Wegmann's porcelain rollers and four sets of chilled iron rollers, the wheat garners, the flour bins over the packers, the bran bins and three two-reeled bolting chests for dusting middlings. The fourth and fifth floors contain the bolting chests, in which there are forty reels, four large-sized bran dusters, fourteen purifiers and the exhaust fans from the stones. On the sixth floor are the gearings to drive the bolts, heads of elevators, aspirators, first dust room from purifiers, etc. The attic contains two reels, machinery to drive the passenger elevator that runs from the top to the bottom of the mill, dust rooms, etc.

The elevator and cleaning rooms connected with the mill are 132 feet long, 40 feet wide, and have a total height of 88 feet. The elevator is divided into twenty bins, each holding 6,500 bushels, and, therefore, has a capacity of 130,000 bushels, although more can be crowded into it. The basement is built of stone and the rest of the building of "Lamire" walls, covered with corrugated iron. The cleaning rooms are in the elevator building and next to the mill. The machinery is arranged in sets of four machines on each floor, and consists of two large brush machines, four smutters, five separators, two cockle separators and a large suction fan. Between the mill and elevator is an archway 30 feet wide, with two railroad tracks and a wagon track running through it. These tracks are provided with a transfer table, so that cars may be changed from one track to the other, and switched without employing an engine, as the transfer table connects with the power that drives the elevator. Under the table there is a large track scale. The space above the tracks is used for storing bran and offal, which may be drawn directly into the cars.

The mill and its accompaniments were constructed with a view to their efficiency and not of their cost to the proprietors. The mill contains every appliance of a first-class modern "new process" mill, and has a capacity of about 1,000 barrels per day, and employs about twenty-five men. In connection with the mill, but in separate buildings, are the cooper shops and warerooms. Machinery is used for making the barrels, the power being transmitted to the cooper shop from the main building by wire rope.

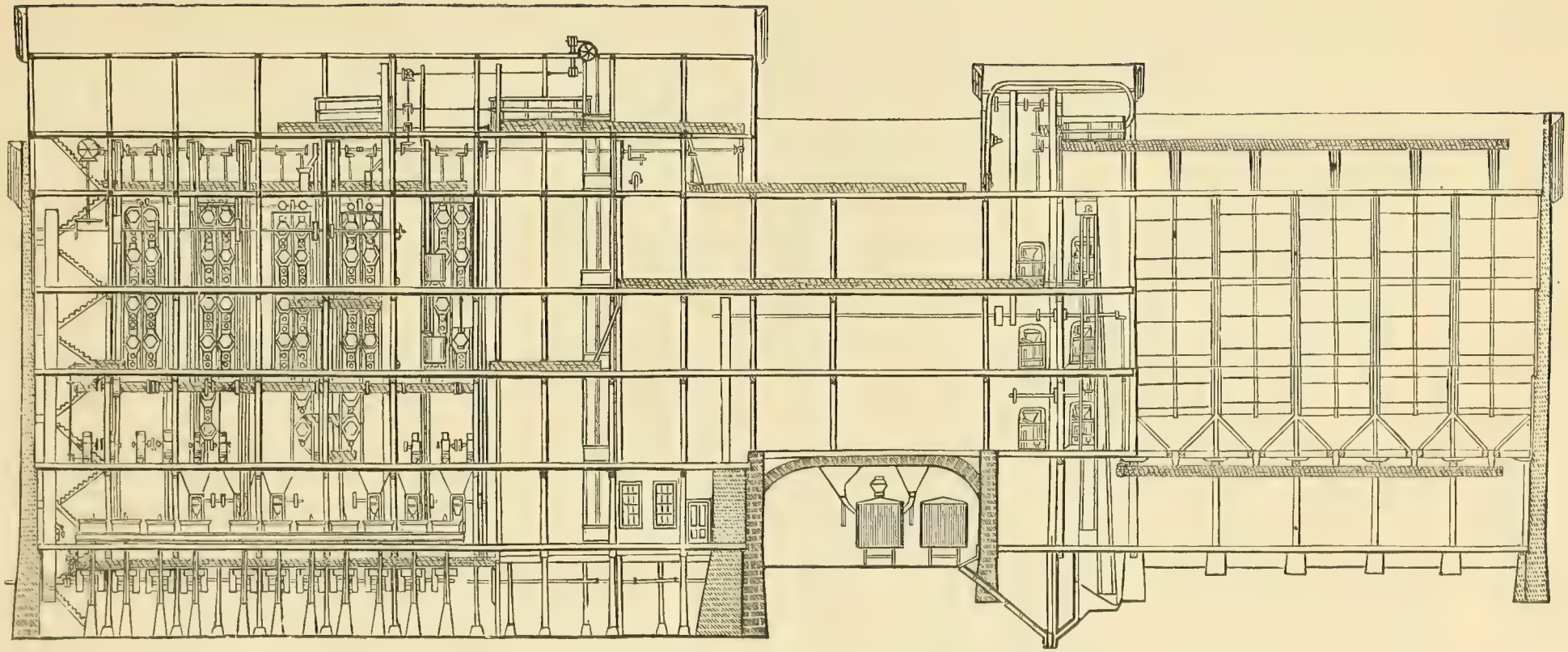
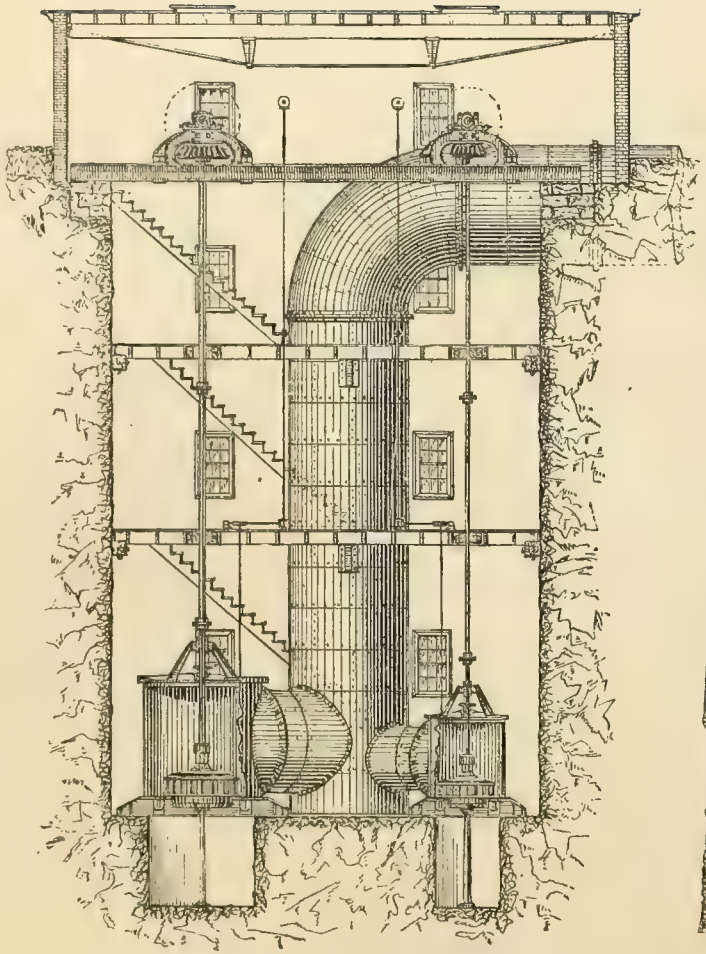
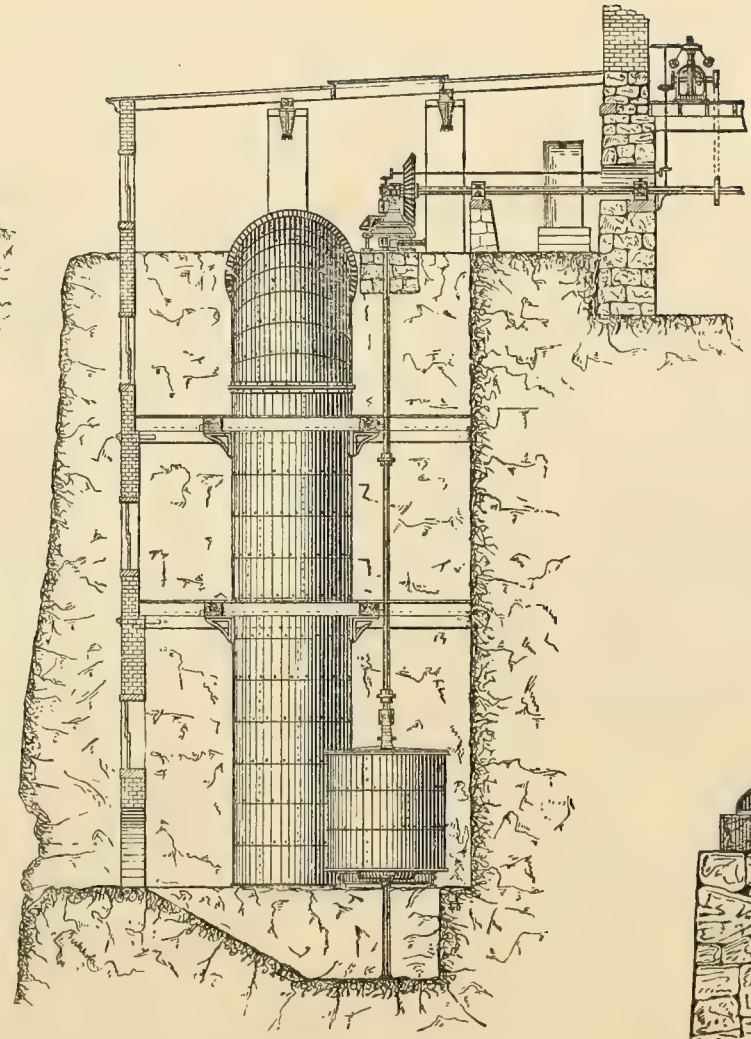


Fig. 8.—Sectional Side View of Niagara Falls Mill and Elevator.

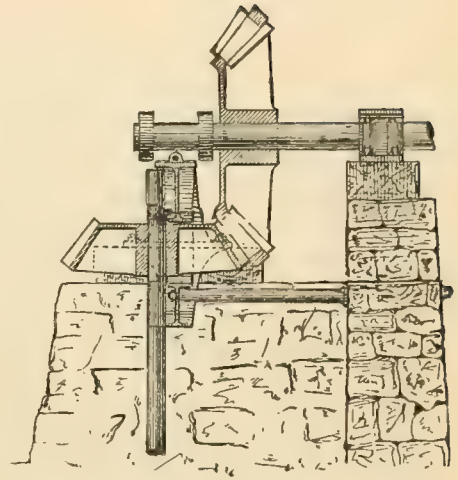


Front Elevation.

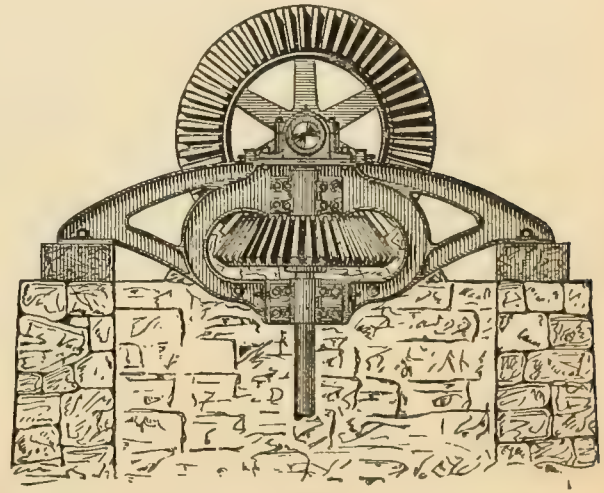
Wheel Pit, Flumes and Shafting.



Side Elevation.



Section.



Front Elevation.

Iron Bridgetree and Gearing over Water-Wheel.

Fig. 9.—WHEELS, &c., NIAGARA FALLS MILL.

Giving 1,000 horse-power, with 52 feet head, as designed and built by Edw. P. Allis & Co., Milwaukee, Wis.

Fig. 9 shows in detail the wheel pit, turbines, iron flumes, the steel shafting, main driving gear and iron bridgetree supporting the same and regulator, forming the magnificent power of the Niagara Falls mill just described. This is perhaps the finest water power in the world, and was designed and built expressly for that mill.

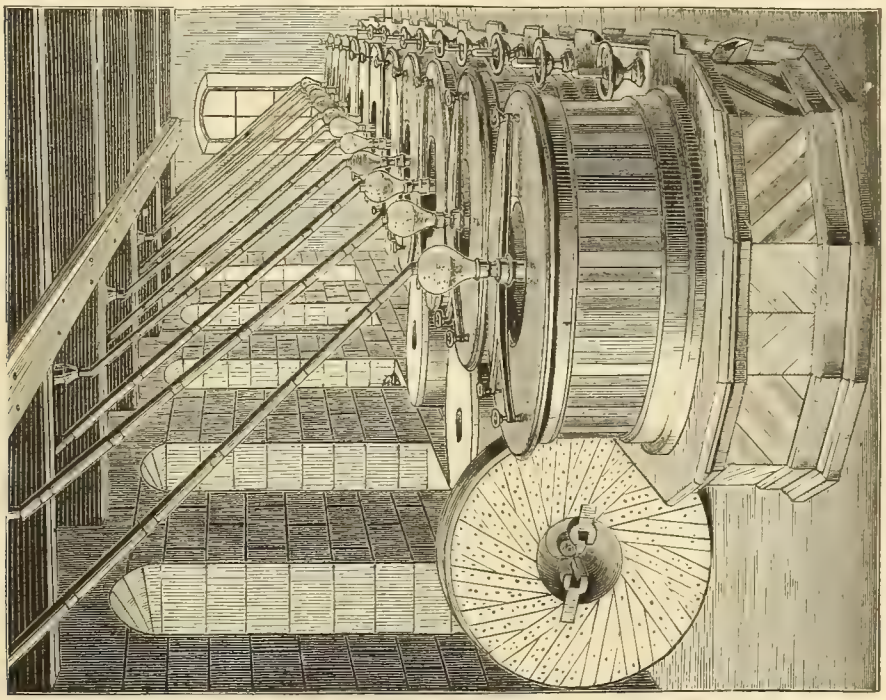


FIG. 11.—NIAGARA FALLS MILL.—LINE OF STONES.

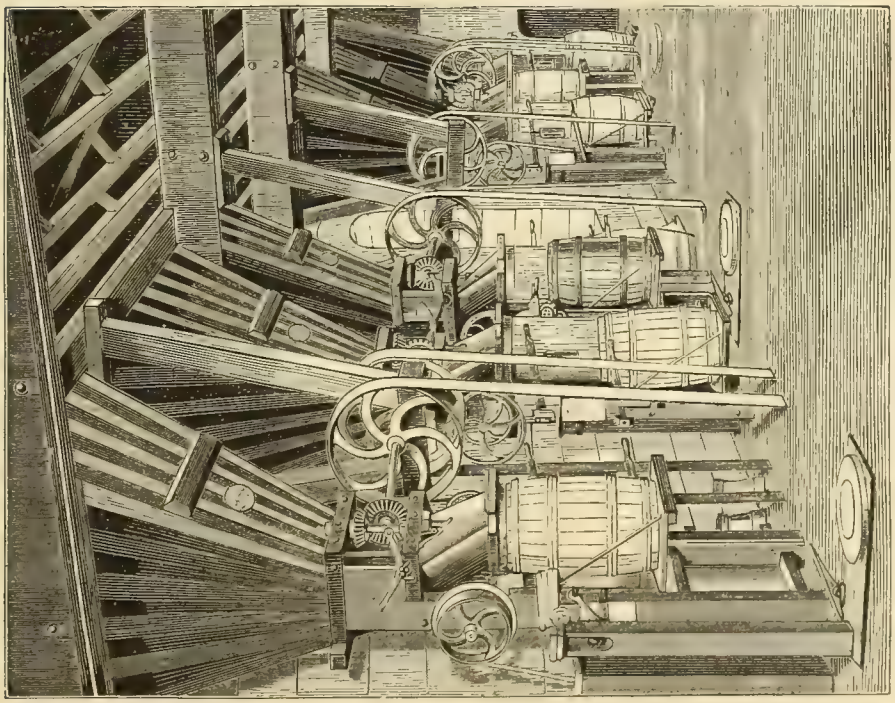


FIG. 10.—NIAGARA FALLS MILL.—PACKERS.

Figs. 10 and 11 are made from photographs taken in the Niagara Falls mill, and show the packers and one line of eleven runs of 4½-foot stones. The finish of the top of hurst frame, the curbs, silent feeders, lighter screws, etc., is first class.

The "Excelsior Mill" Minneapolis, Minn.—This mill was designed and built in 1877, by E. P. Allis & Co. for the Hon. D. Morrison, of Minneapolis, who leased it to C. A. Pillsbury & Co., by whom it is now

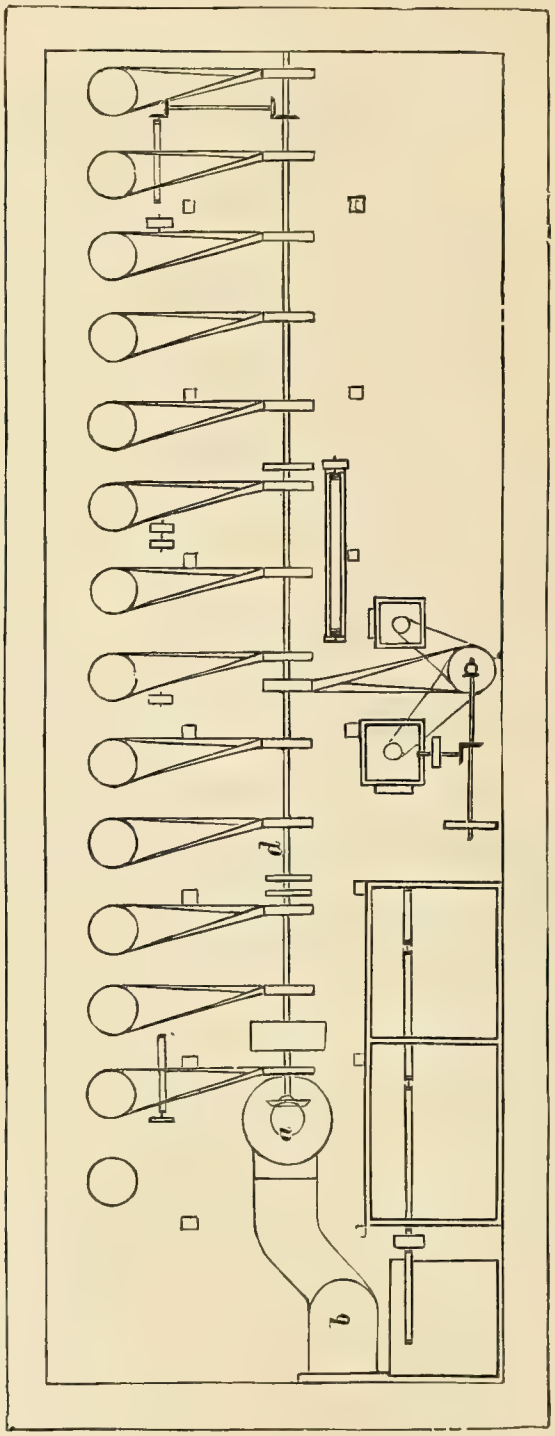


FIG. 12.—PLAN OF BASEMENT OF EXCELSIOR MILL.

run. It had originally thirteen runs of 48-inch violet millstones, set on an iron hurst frame and driven by a quarter-turn belt from the main line shaft. This shaft was driven direct from the water-wheel by a large bevel mortise

wheel and pinion. A large belt from the main line shaft drives a line of shafting in the fifth story of the mill, and from this all the bolts, elevators and purifiers are driven. There were twenty-three reels in the mill and ten

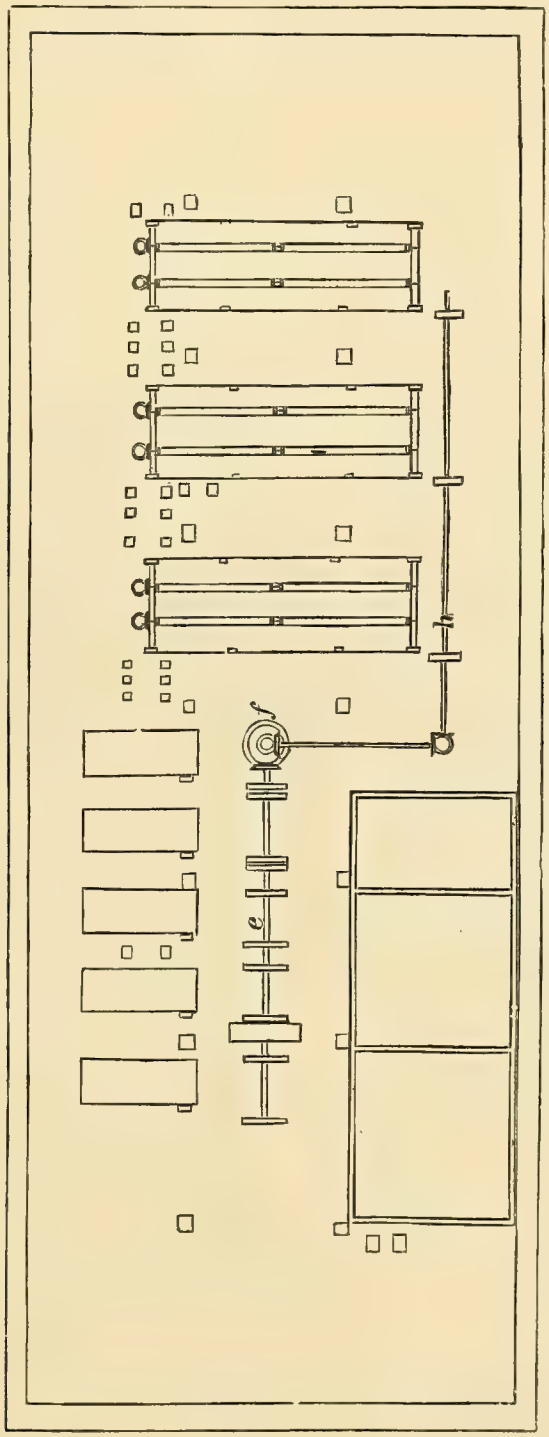


FIG. 13.—PLAN OF BOLTING FLOOR OF EXCELSIOR MILL.

purifiers, the middlings being properly graded on to the latter. In the accompanying diagrams Fig. 12 shows the plan of the basement, Fig. 13 the

plan of the bolting floor, Fig. 14 the attic plan, Fig. 15 a sectional side view and Fig. 16 a sectional end view of this mill.

The builders completely remodeled this mill in 1879, taking out 11 runs

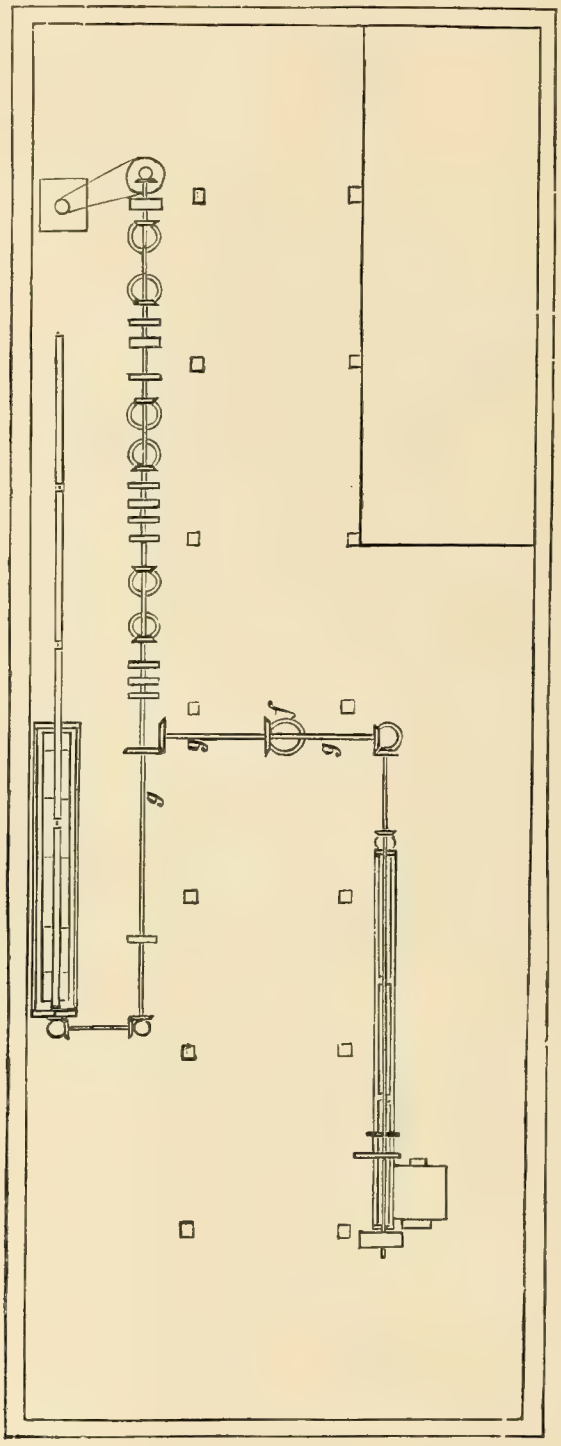


FIG. 14.—PLAN OF ATTIC OF EXCELSIOR MILL.

of stones and substituting grooved chilled iron and porcelain rolls, making it a gradual reduction roller mill.

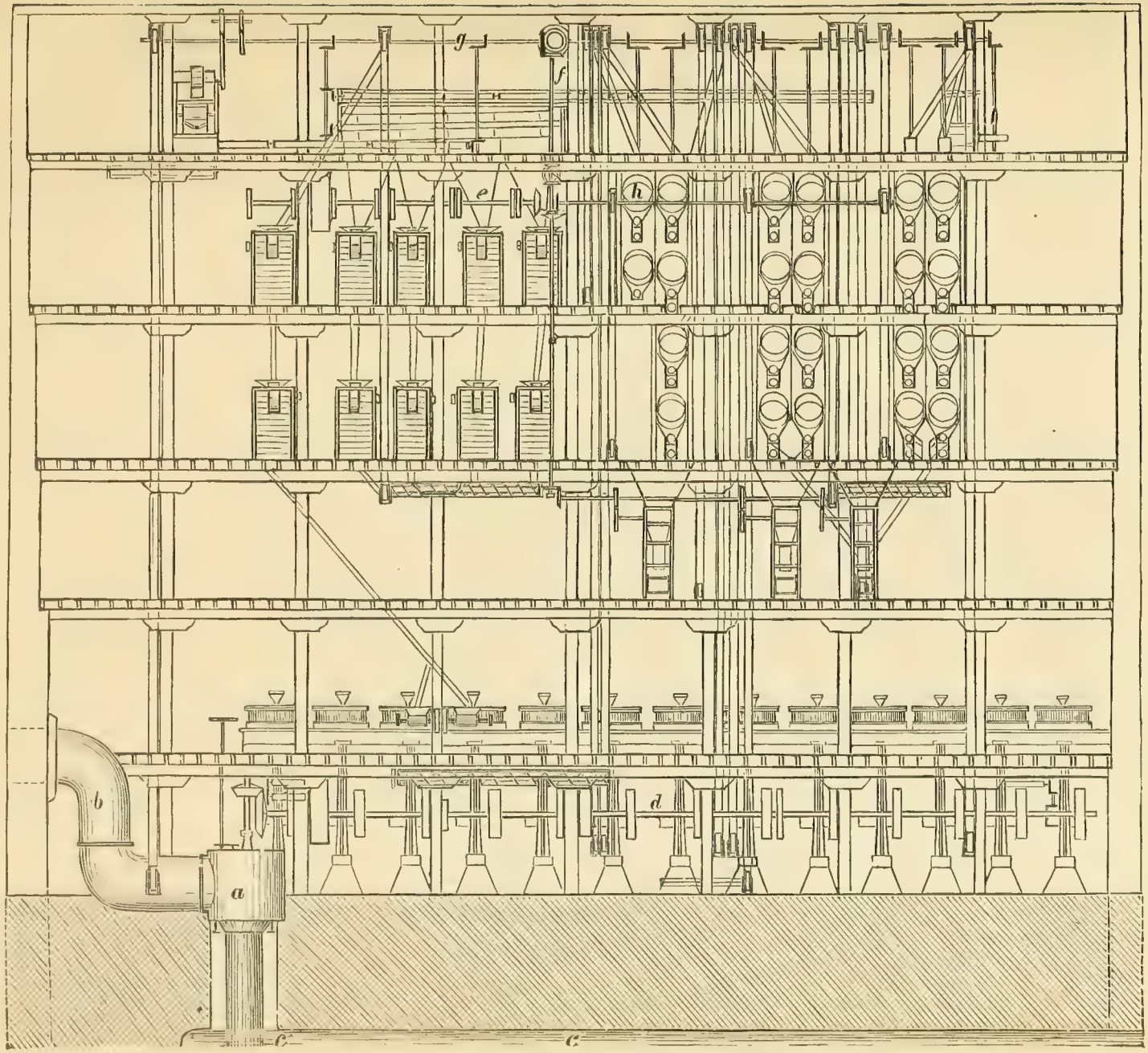


Fig. 15.—Sectional Side View of Excelsior Mill.

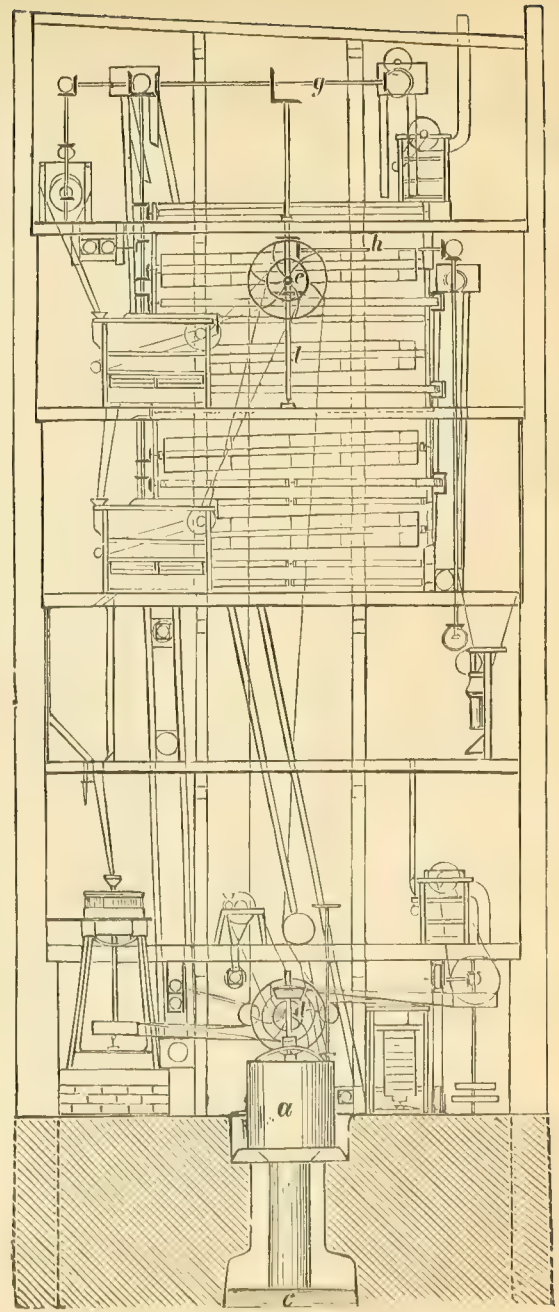


Fig. 16. Sectional End View of Excelsior Mill.

The Burned Yaeger Mill, St. Louis, Mo. (Allis).—This large and beautiful mill was designed and built in 1876, and finished complete from the foundation up in ninety days from signing of contract. The building is 160 feet square on the ground. In Figs. 17, 18 and 19: "A" is the mill proper, 80 by 86 feet, consisting of basement, four high stories and attic. "B" is the engine house, 16 by 53 feet; "C" is the boiler house, 48 by 53 feet; both of these are covered by one roof. The stack is 10 feet square at base and built up octagonal. "E" is the wheat drying house, 27 by 64 feet. "F" is the coal room, 10 by 70 feet. The cleaning house consists of the basement, in which is placed a small steam engine to pump water, and a repair shop, and has three stories above basement. The large room, "G," is used as a store house, 60 by 52 feet. "H" is the grain house, 60 by 28 feet. The whole basement underneath "G" and "H" is intended for store room, and the height is such that the barrels can be rolled directly into the cars. Above "G" is the bran storeroom, 52 feet wide. The wheat bins are 44 feet high. The railroad track runs alongside of the mill, from which to receive wheat and ship the product of the mill. The wheat is rapidly taken from the cars and elevated into the bins, and from the bins is taken to the cleaning machinery by conveyor and elevator. It is first put through three large separators, then through four dusters and two brush machines, and thence into two grading reels, from which it is put through eight large chilled iron crushing rolls, for the purpose of opening the wheat without making flour, from which it goes into two more dusting reels, for the purpose of getting rid of the dust and loose germs. It is now elevated and conveyed into the mill proper. This contains twenty runs of $4\frac{1}{2}$-foot stones and fourteen of Wegmann's patent porcelain roller mills. There are five 4-reel chests and one 2-reel chest (reels 32 inches by 25 feet) on the fourth floor. On the third floor are five 4-reel chests and one 2-reel chest, and on the second floor are two 4-reel chests; these latter, however, with reels, are only 18 feet long. Under each reel are double conveyors. In the attic there are four middlings grading reels and six 15-feet reels for roller products. The system of bolting and rebolting is very complete, and the bran is scalped off on the first reels. The system of purifying middlings is elaborate and perfect. The clean middlings from the upper machines are spouted to the rolls or stone, and the returns from these machines pass into other machines on the lower floor, and from these are taken to the rolls, etc.

The machinery is driven by an automatic cut-off engine, and the boilers are made of steel. The stones are firm on iron hurst frames and are placed on either side of the main line shaft, from which they are driven by a quarter-turn belt. The spindles are $5\frac{1}{2}$ inches in diameter and 10 feet long.

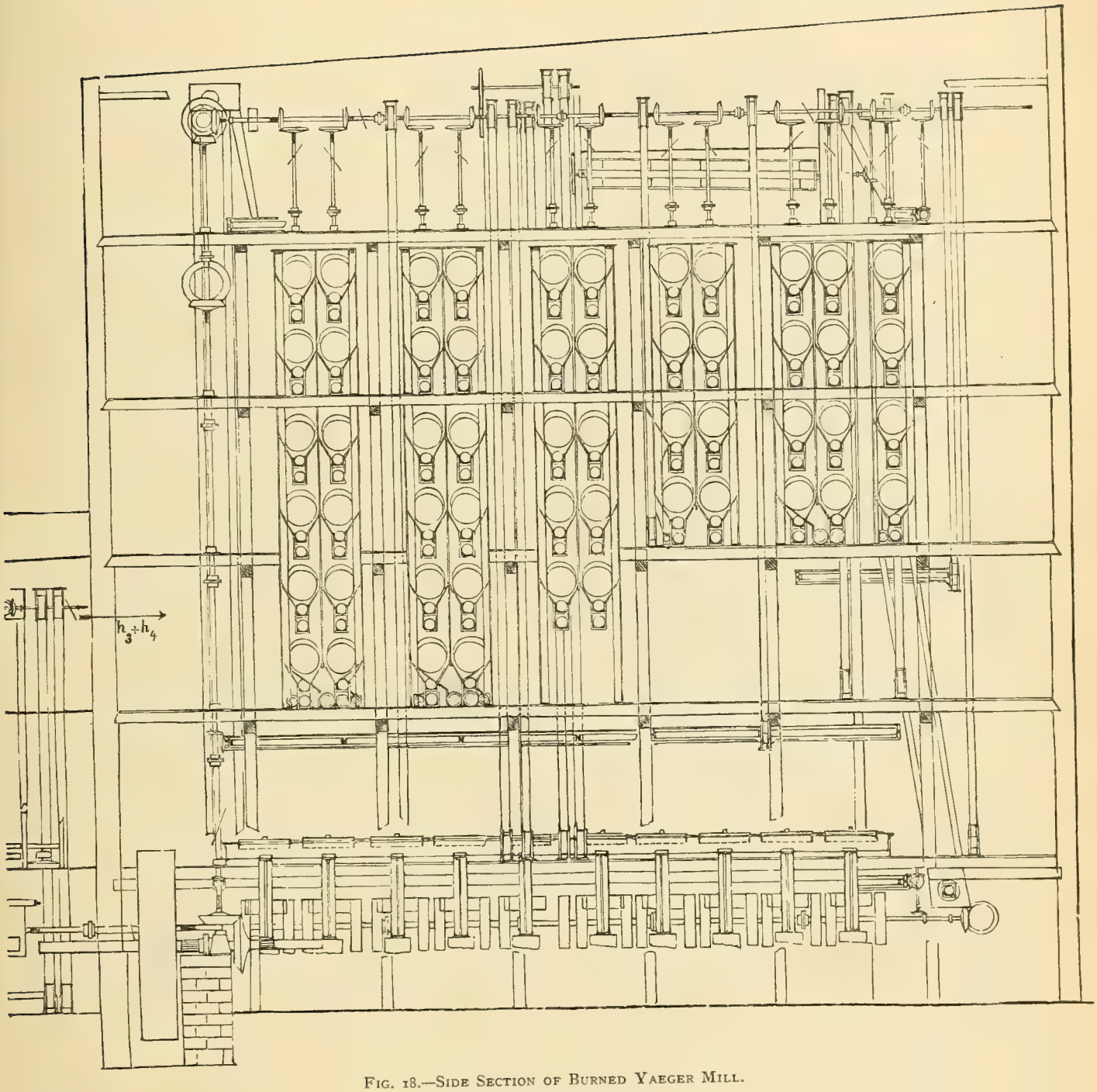


Fig. 18.—Side Section of Burned Yaeger Mill.

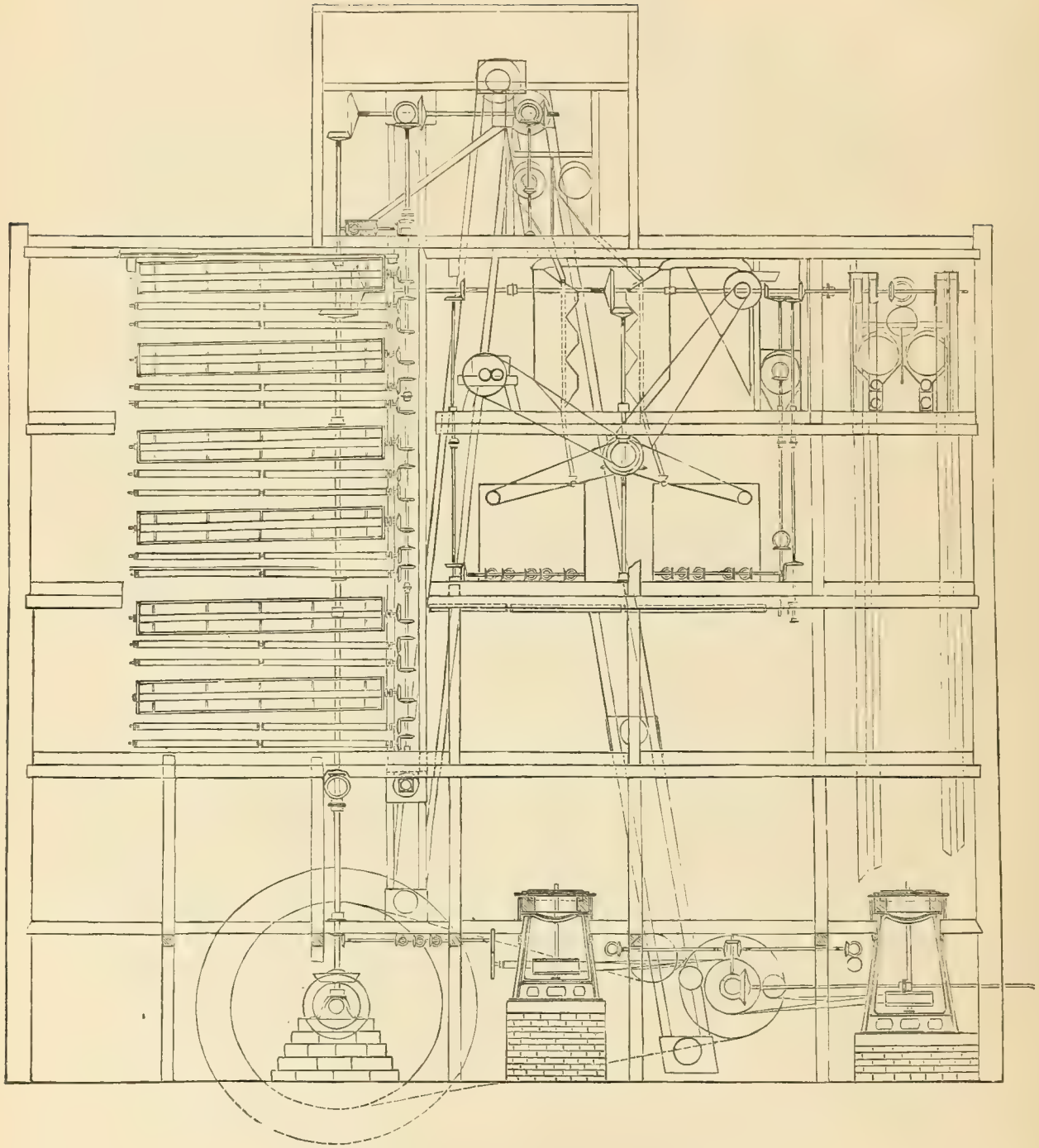


Fig. 15.—End Section of Burned Yaeger Mill.

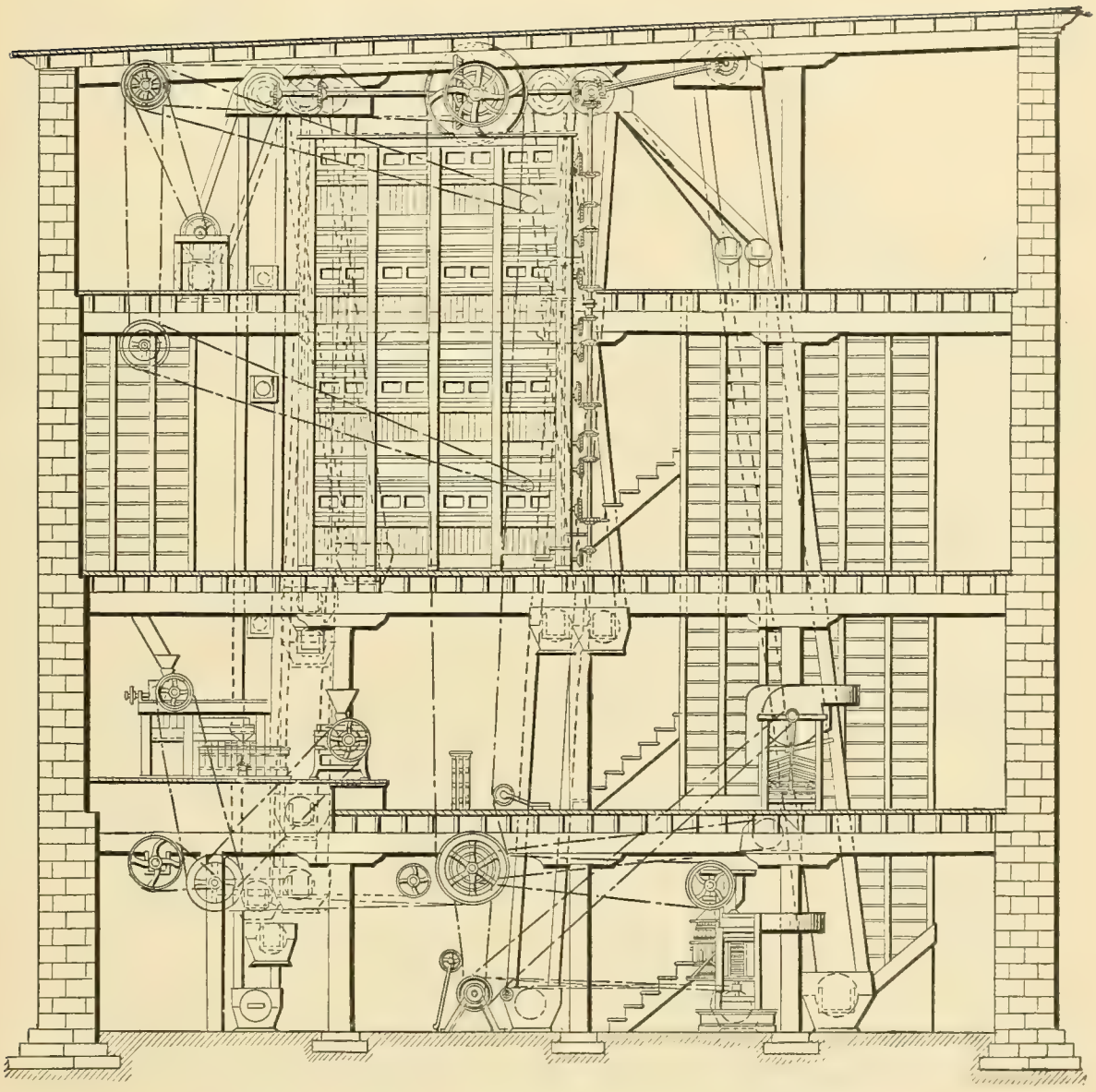


Fig. 20.—Deseronto Mill.—End Elevation. (J. T. Noye & Sons.)

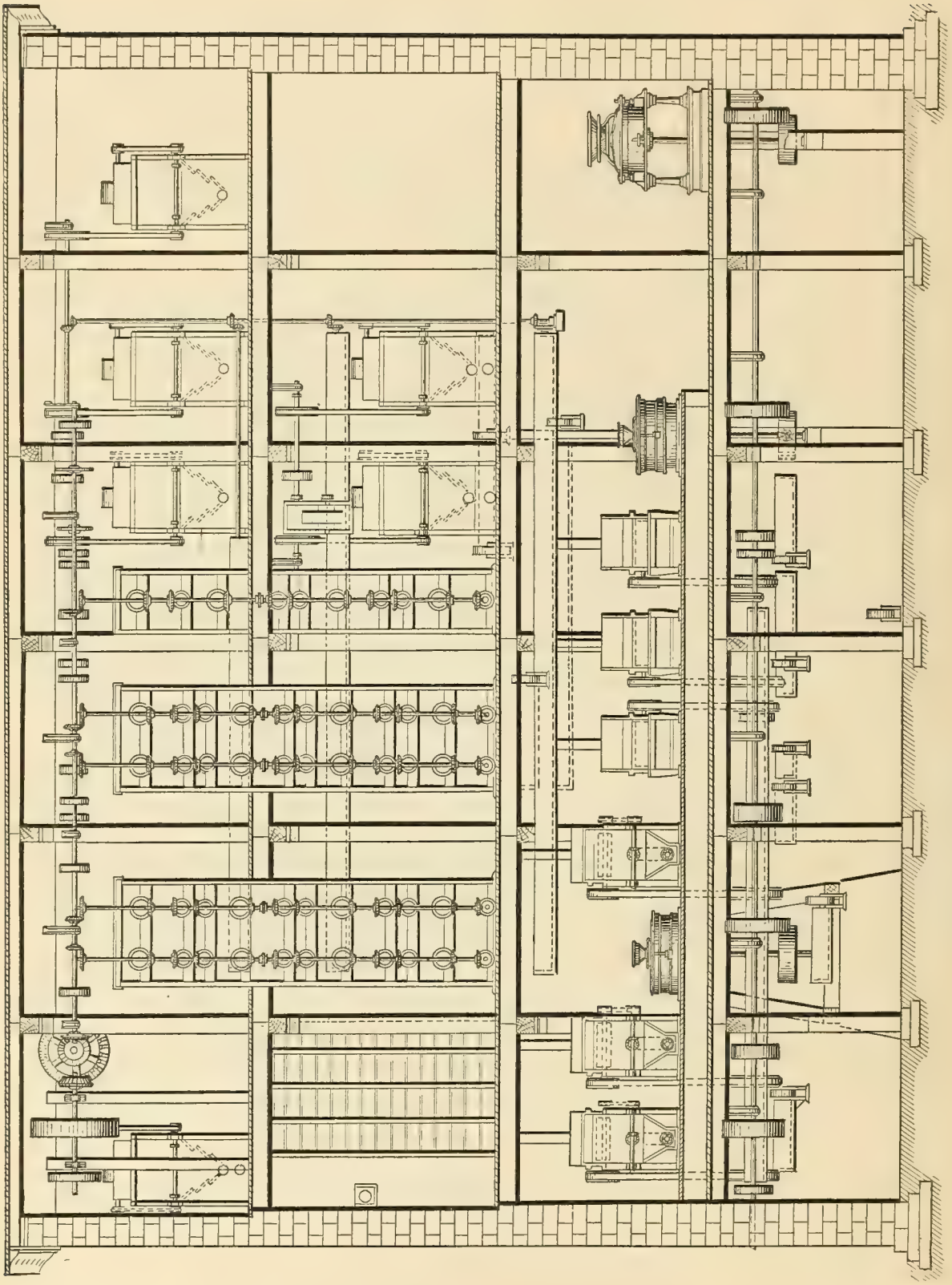


Fig. 21.—Deseronto Mill.—Side Elevation. (J. T. Noye & Sons.)

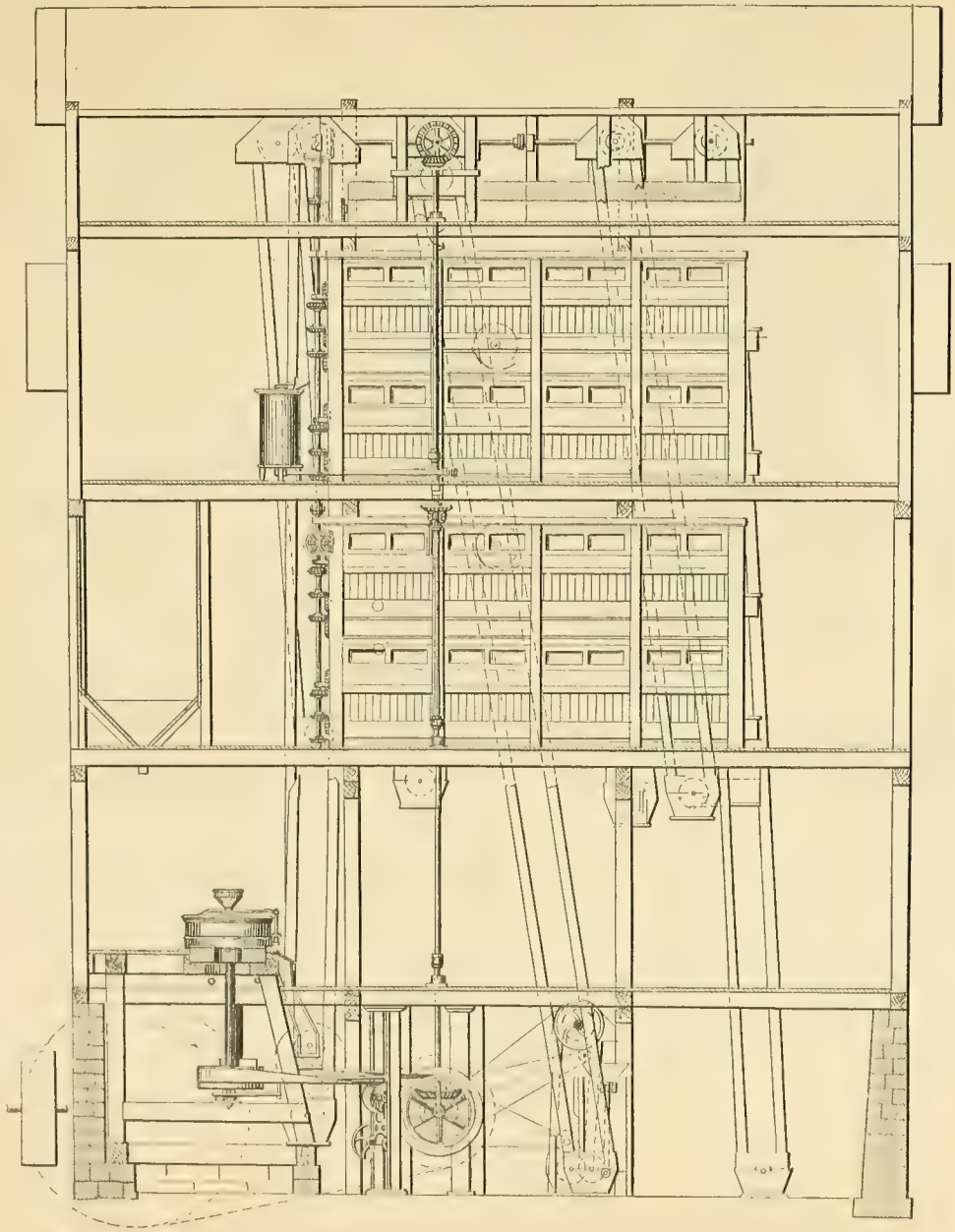


Fig. 22.—Side Section of Five-Run Mill, Designed by Jno. T. Noyé & Sons, Buffalo.

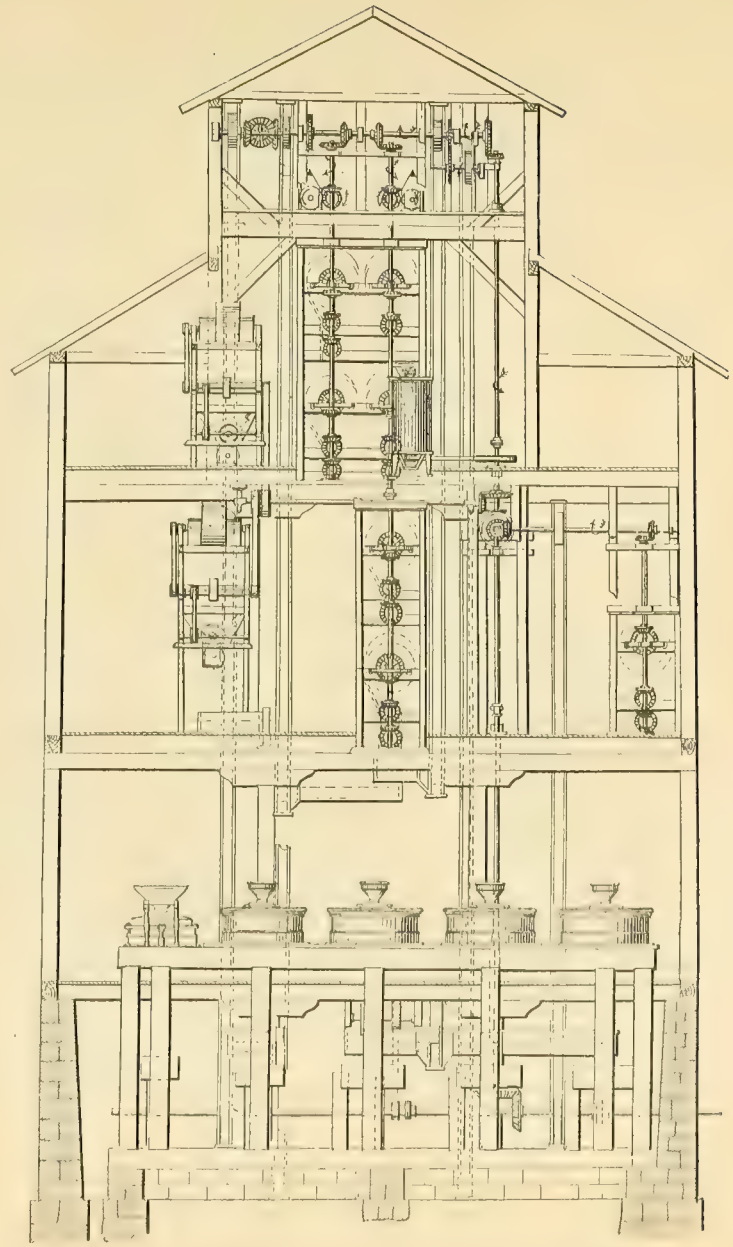


Fig. 23.—Cross Section of Five-Run Mill. (Noyé.)

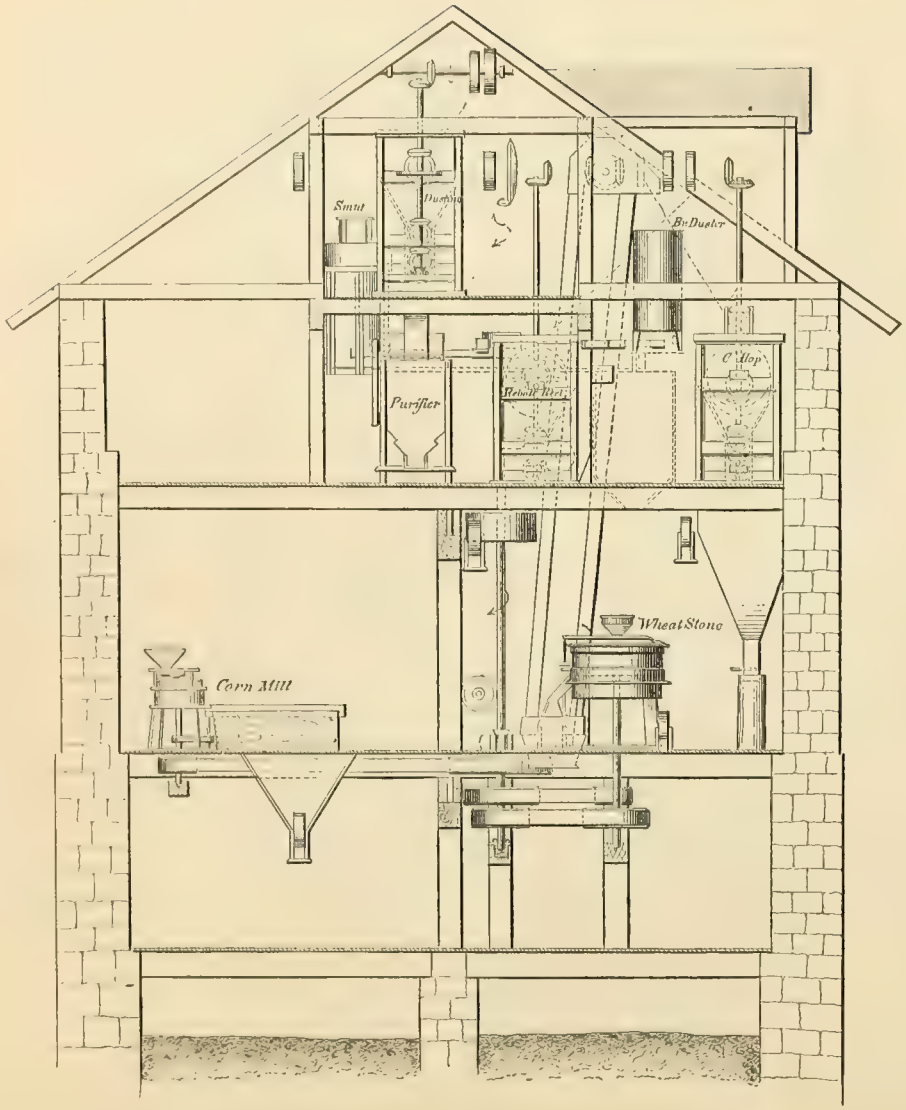


FIG. 24.—CORN MILL. (NOYE.)

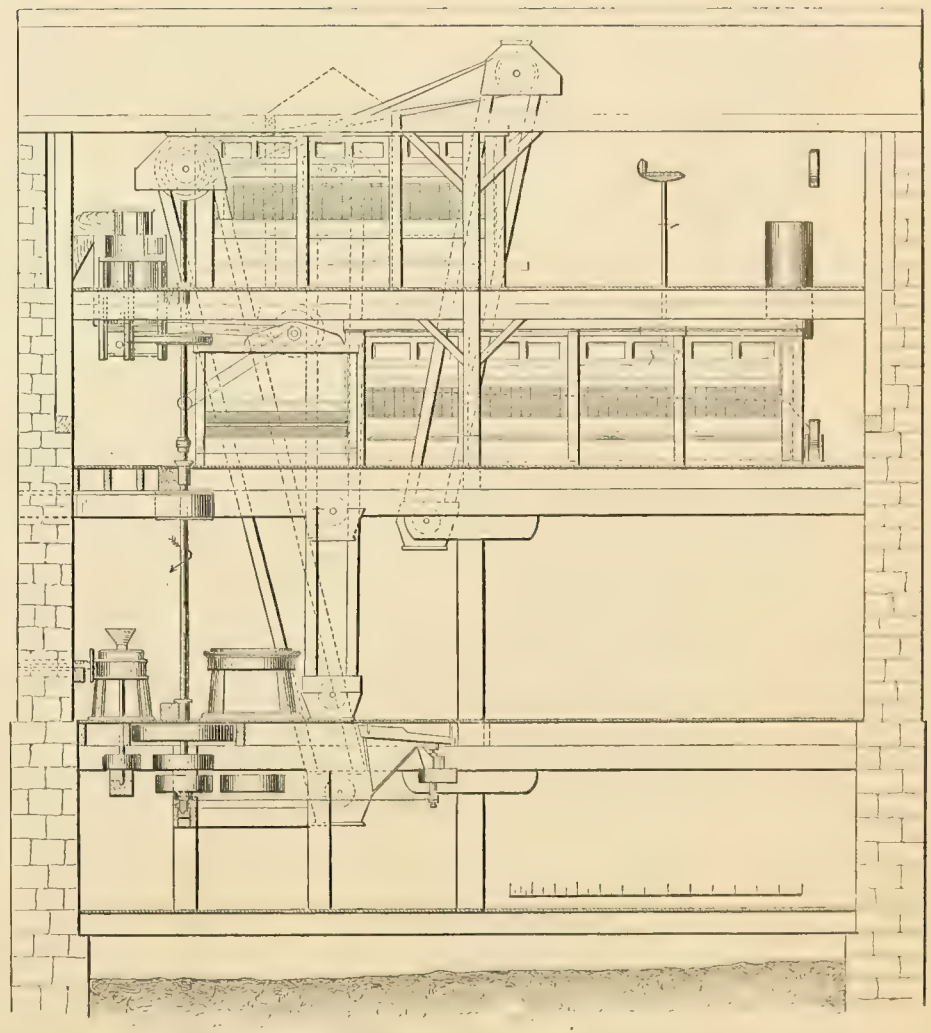


FIG. 25.—CORN MILL—SIDE VIEW. (NOYE.)

Two-Run Buhr Mill.—Fig. 24 shows a small corn mill with one run of stones for wheat and another for corn, John T. Noye & Sons designers. It is shown in side view in Fig. 25.

Seven-Run Mill (Richmond City Mill Works).—The illustrations given in Figs. 26, 27 and 28, show a new process stone mill especially designed to make the entire product a straight grade of a high quality. There are five runs of buhrs for wheat and two for middlings, four purifiers, one bran duster, two flour packers, one bran packer, one pair of bran rolls, one pair of middlings rolls, thirteen elevators, sixteen reels arranged in two 8-reel chests, and one separate reel for grading. The wheat goes from the stock bins to the five wheat stones. The product of the five runs

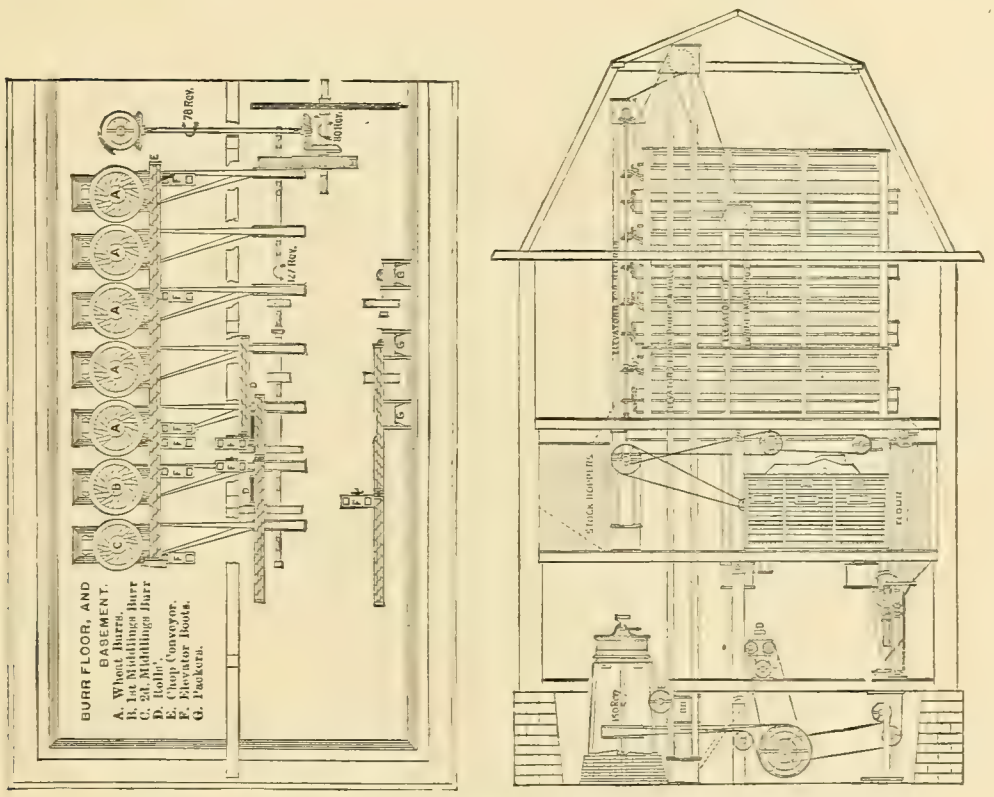


FIG. 26.—SEVEN-RUN MILL (RICHMOND CITY MILL WORKS).—FIG. 27.

is equally divided between the two upper reels in the upper chest, there being one elevator for each. These upper reels are clothed to take a part of the flour off at the head and all middlings off at the tail. The middlings which come from the tail of the two upper reels are dusted in the lower reels, and then pass through the grader to the several purifiers. After purification the middlings go to the two runs of middlings stones, and are then bolted separately on five reels of the other 8-reel chest, arranged precisely like those in the first chest. Two reels in the same chest are used for the products from the rolls, and all flour is finished on the remaining reel and thoroughly mixed before going to the packers, or, if desired, that portion of the flour made from the middlings is packed separately as a patent brand.

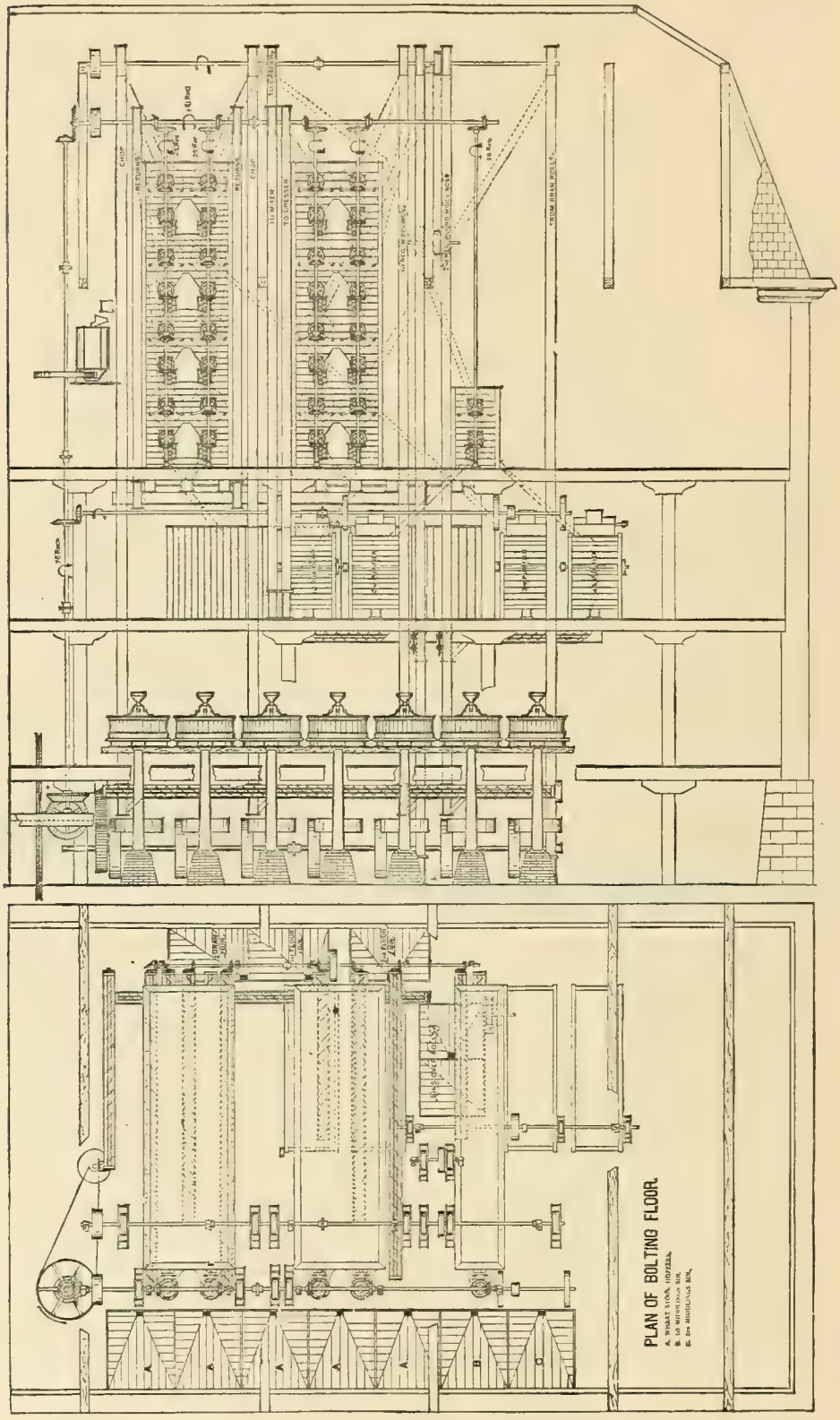


FIG. 28.—SEVEN-RUN MILL (RICHMOND CITY MILL WORKS).

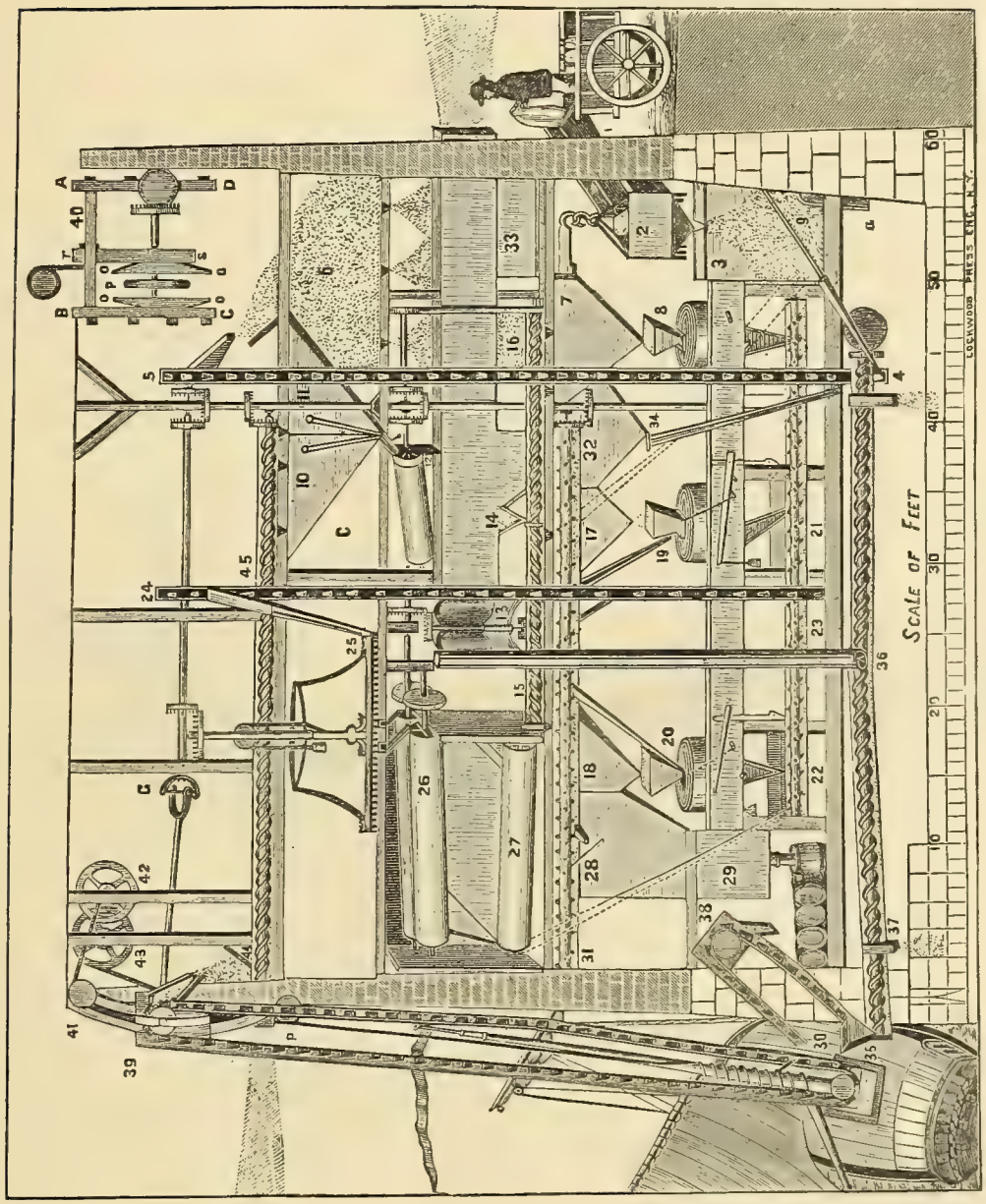


FIG. 29.—OLIVER EVANS' MODEL MILL, A. D. 1790.

Oliver Evans' Model Mill.—Fig. 29 is a copy of the panorama of a complete automatic mill designed and drawn by Oliver Evans about 1790.

The Mill Office.—There is no manufacturing business, that has reached the same perfection of working, which can compare with the miller's in mean, out of the way, dirty and uncomfortable offices. Stuck away under some back stairway, out of the reach of daylight, they become the receptacle for old cast-off overalls, samples and bethumbed papers. Everything is covered with a mixture of dirt and flour, as if those two went hand in hand in the output of the mill. This is a wrong principle. Aside from the consideration of cleanliness it does not pay to keep a dirty office. The office should be well lighted and ventilated, and should, if possible, be situated on that side of the mill receiving the least dust. Its size, of course, must be decided by each miller. It should contain a closet for garments and be divided into two compartments: one for the miller's use and one for visitors, so that the dusty garments of the miller may not come in contact with the clothes of his visitors. Fig. 30 represents a model mill office planned by

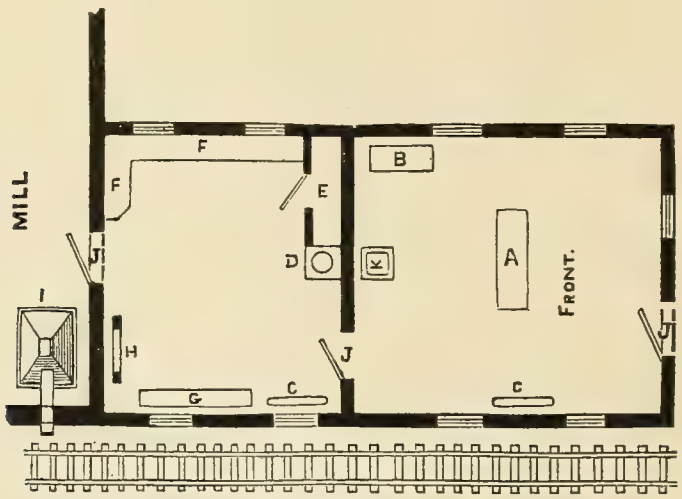


FIG. 30.—MILL OFFICE.

A—High Desk. B—Chair Desk. C—Heaters. D—Washstand. E—Wardrobe. F—Sample Cases. G—Testing Table. H—Beam of Railway Scale. I—Railway Scale. J—Doors. K—Safe.

Nordyke & Marmon. This plan is perhaps a little more elaborate than some mills can afford; but the principle on which it is drawn is, "Everything in its place and a place for everything," and if this principle, combined with cleanliness, shall be carried out in all the mills, the offices will be much more attractive and more convenient.

CHAPTER III.

MILLING DIAGRAMS.

Preliminary Mill Plans.—The diagram given, Fig. 31, was drawn by A. Forrest, now with the Novelty Iron Works, of Dubuque, Iowa, and is called by him a "Panorama of the Mill," because it brings all of the processes of the mill before the eye at one view. The diagram was not designed to show the arrangement of a first class or a complete mill of any class, but was intended merely to show a method of sketching out milling processes by men who are millers and not machinists. The processes are sketched out as any miller might do it, without any reference to the location of the various devices in the building. Every practical miller and millwright will readily understand the construction of the several parts required to carry out the processes as sketched. While this plan does not show a complete modern mill, yet, if properly arranged as to machinery, it would make a very good custom or exchange mill, of small capacity.

In arranging the machinery of this mill, the millwright would, probably, place the "receiving hopper" somewhere on the first floor, not, as in the sketch, clear in the top of the mill. The "separator" could be placed on the first floor and the "smutter" in the basement. The stones, located so far apart in the drawing, would all be placed side by side on one hurst frame. The reels and conveyors shown would be placed in chests, standing on the first floor side by side, and extending to the required height. The "mixing conveyor" would be placed crosswise under the flour spouts of the bolting chests, or some patent mixer would be substituted for it. The "packer bin" would be located on second floor. The purifiers would find a place on second floor, or one on this floor and one in the attic. The dusting and scalping reels might be in separate chests and both located in the attic, immediately over the chop and middlings flour bolts. The "stock bins" and "middlings room" would be side by side, over the buhrs.

By taking a pencil and following closely the continuous lines of arrows, the reader will not only be able to follow each and every product through the mill, but will see the utility of this method of making preliminary plans of mills. We trace the wheat from the receiving hopper through the separator and smutter to the stock bins, which ends the "cleaning process." From the stock bins we trace the grain to the two runs of stones, which it leaves in the form of what is called by many millers "chop." The chop, being thoroughly mixed, is next taken to the head of the scalping reel. The product of the

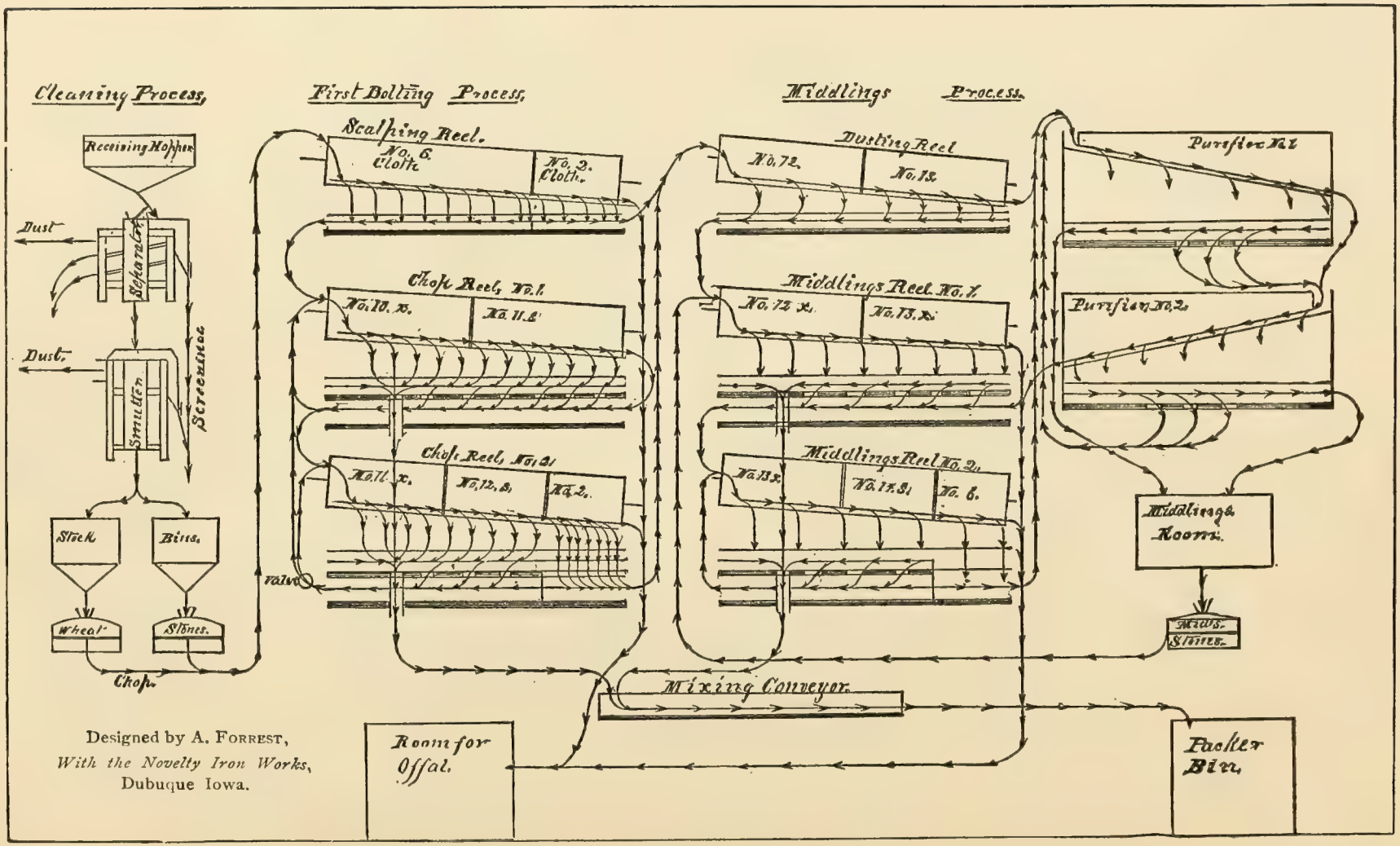


Fig. 31.—Preliminary Mill Plans.

fine cloth on this reel is carried, by means of a conveyor, into the head of the chop reel No. 1, which has two conveyors under it, the first of which conveys each way to the flour spout near the head end of the reel. Cut-offs from this

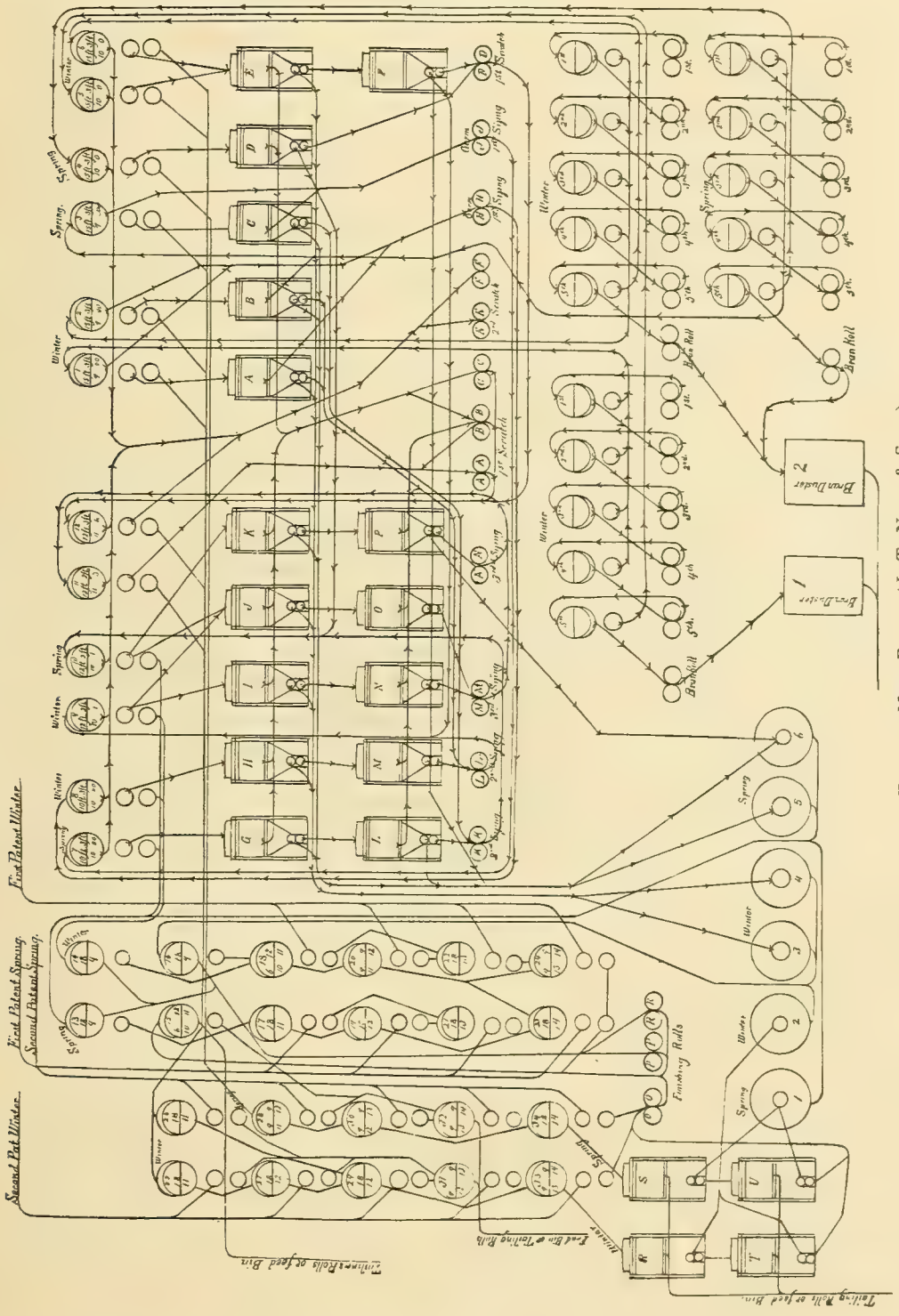


FIG. 32.—MILL PLAN. (J. T. NOYE & SONS.)

spout to near the tail of the reel allow so much of the product of this reel as is pure to go through the spout to the mixing conveyor. By the second conveyor the cut-off, or such portion as is not sufficiently bolted, is carried, with

what passes over the tail of reel No. 1, to the head of chop reel No. 2. Here, by the use of a similar arrangement of conveyors and cut-offs, flour is taken off to any desired extent, and run, with the flour of the No. 1 reel, to the mixer. The cut-off from this reel, by means of a properly arranged valve, is carried either into the upper or lower reel as the miller shall choose. All that is necessary to change the direction of this cut-off portion is to pull a string. What passes through the No. 2 cloth, on the tail end of the scalping reel, falls into the conveyor and is run into the head of the "middlings dusting reel." All middlings that may have passed through the chop reels will be taken out through the coarse cloth at the tail of the lower reel, and, as shown by following the arrows, join the middlings from the scalping reel and go into the dusting reel. What passes over the tail of the scalping reel joins similar material from the tail of the second chop reel, and goes to the room for offal. What is left is now safely cornered in the dusting reel. The product of this reel (what passes through the cloth) goes through the conveyor into the head of middlings reel No. 1. The dusted middlings, passing over the end of the cloth of the dusting reel, goes to purifier No. 1. By following the arrows, we trace the middlings through the machine to the middlings room. The tailings from purifier No. 2 go to the room for offal, although any other disposition may be made of them, if desired. From the middlings room the purified middlings pass to the "middlings stones." From the middlings stones we follow the reground product, by the arrows, into the head of middlings reel No. 1. In this chest there is the same system of conveyors and cut-offs as in the first flour chest, and the process is the same, differing only in the qualities of the silks. To the processes here traced out, a cockle machine and brush may be added to the cleaning process; a grading reel to the middlings process, and a bran duster and even corrugated rolls for cleaning bran and tailings may be added. All of the cloths may be graded to suit the miller who operates the mill.

In Fig. 32 is shown a plan for a mill, as laid out by John T. Noye & Sons, Buffalo, N. Y.

CHAPTER IV.

POWER.

Waste of Power—Relative Cost of Steam and Water Power—Steam vs. Water—Power per Barrel of Flour.

Waste of Power.—There are some places where water is cheaper than steam power, and some just the other way. There are places where water ought to be cheap, but it is not. An instance of this is to be found at Moline, Ill., where there is one of the best water powers in the country; but the water power company charges so much for water rents that many of the manufactories are changing to steam power. The cost of fuel may be greatly increased by an ignorant or careless engineer or fireman; by bad boiler setting; by a wrong type of engines, or a good type which is of the wrong size or badly set, or allowed to get out of repair. Slipping belts, or over-taut belts, will waste many pounds of coal or cubic feet of water. Sometimes ten dollars' worth of oil will save twenty dollars' worth of coal Too low or too high a chimney may waste coal. An unprotected boiler will take more coal to make the given weight of steam than one that is properly protected, and the steam will not be so dry. Gearing that is made by some country establishment by rule of thumb, or mortise gears in which the cogs are made by hand, will use up a good deal of power beside giving plenty of backlash.

Relative Cost of Water and Steam Power.—The cost of the water equipment at Lowell was for canals and dams $100, and for wheels another $100 per horse-power; but this was too great. At one place reported the expense was $175 per horse-power. The cost at Penchet $113.50 per horse-power; with wooden dams and lower grade wheels, the cost is about $50 per horse-power, and, although this would be less permanent than the more solid installation, it would outlast any steam machinery. Fall River cost of steam equipments, exclusive of foundations and engine house, runs from $100 to $115 per horse-power. A Boston authority gives $115 per horse-power for nominal 300 horse-powers and upward, inclusive of foundation and masonry. A Portland authority places it at $100 per horse-power. A Western manufacturer says that, with six to eight feet head, the average cost for wheels, flumes, etc., is not far from $200 per horse-power, while at another point, with eighteen feet head, it does not reach $50 per horse-power. (The actual cost of the steam equipment in the water works in the various cities of the United States varies from $150

to $300 per horse-power.) The amount of masonry and excavation necessary vary greatly. We may say that the turbine itself and its installation, exclusive of excavation and masonry of races, etc., is from $40 to $50 per horse-power. It must be borne in mind that estimates which would be applicable to Wilmington, Delaware, for instance, would not apply to Holyoke, Minneapolis, Appleton, etc. As most water-power contracts are awarded, the laws permit running at night, without extra charge,—no mean item of advantage.

Steam vs. Water.—A steam mill has this advantage over a water mill, that it is almost entirely independent of the situation. It can be placed to suit the convenience of receiving grain, shipping flour, etc. But the water mill, as ordinarily constructed, must be built near the power, which, in many cases, is of itself a disadvantage, by reason of being there exposed to danger from high water and of having no dry basement for cleaning machinery or for storage. This difficulty might be largely overcome by the use of wire cable to convey the power of the fall from the wheel to the mill, which might then be put where convenient for everything.

Power per Barrel of Flour.—At the Northwestern roller mill, Minneapolis, a 30-inch turbine, under thirty-eight feet head, and tabled at 311 horse-powers, turned out for several days 800 barrels of flour per day of 24 hours, which is at the rate of 0.388 horse-power per barrel. The Standard mill, in the same city, with a 44-inch turbine tabled at 320 horse-powers, under twenty-four feet head, has produced 900 barrels per day of 24 hours, being at the rate of 0.355 horse-power per barrel. C. C. Washburn, of Minneapolis, is driving his mills, B and C, with turbines, one of which is rated at 600 horse-powers, with which they turn out 1,400 to 1,500 barrels of flour per day of 24 hours. The Crown roller mill, Minneapolis, owned and operated by Christian Brothers & Co., made during the summer season of 1880, when running full, 1,000 barrels of flour per 24 hours, with a wheel of 400 horse-powers.

CHAPTER V.

WATER-WHEELS WITH HORIZONTAL AXES.*

Kinds of Wheels—Undershot—Breast—Overshot—Vertical vs. Turbine Wheels—The Largest Water-Wheel—Screw Flood Wheels.

Kinds of Water-Wheels.—There are four kinds of water-wheels in common use; overshot, undershot, breast and turbine, the first three having horizontal, and those of the fourth class vertical axes.

The Undershot Wheel.—The earliest water-wheel is the "flutter" wheel; next the undershot—at first with straight radial buckets, then with obtuse buckets, and then with curved, the last developing 60 per cent. of the water power. Undershot wheels are limited in power by the size of the floats and the velocity of the stream. Part of the force is lost at the ends and below the paddles.

The Breast Wheel.—Breast wheels lose a great deal of water unless kept close to the sheeting, and require a large portion of the total fall to be used as head, one foot of fall being equal to two feet of head. This is a disadvantage. In breast wheels the buckets should receive the percussion of the water at right angles, as this prevents the water from flying towards the centre of the wheel and at the same time holds it in the wheel to act by gravity after the stroke; it admits air freely and discharges water freely without lifting it at the bottom. Where the water level varies, the breast wheel adapts itself better to the arrangement of gate than the overshot. Where the level falls, say 18 inches, it draws from the lower gate. The water, as it leaves the breast wheel, is forced away instead of submerging the wheel.

The Overshot Wheel.—Overshots are not good where much power is required in a concentrated form. For high heads they require to be of too great diameter. They are generally made of wood, and are, therefore, liable to decay and give trouble from stoppages for repairs. There is an excessive amount of friction by reason of their great weight, and they are not well adapted for use where the water level varies. In this respect the breast wheel is better, as there can be two or more gates to accommodate different levels. Overshot wheels are more economical, proportionally, at part gate than turbines. They are slow moving and for most manufacturing purposes require too much gearing up to get speed. A 24-foot wheel should

* Detailed instructions for building wooden water-wheels are given in the chapters on Millwrighting.

make about four turns per minute. The fall is the distance between the surfaces of the water in the head race and the tail race. In overshot wheels, throughout that portion of the distance between the surface in the head race and the wheel itself, it acts by impulse only and not by weight. The full outside diameter of the wheel does not have useful effect, but there is some

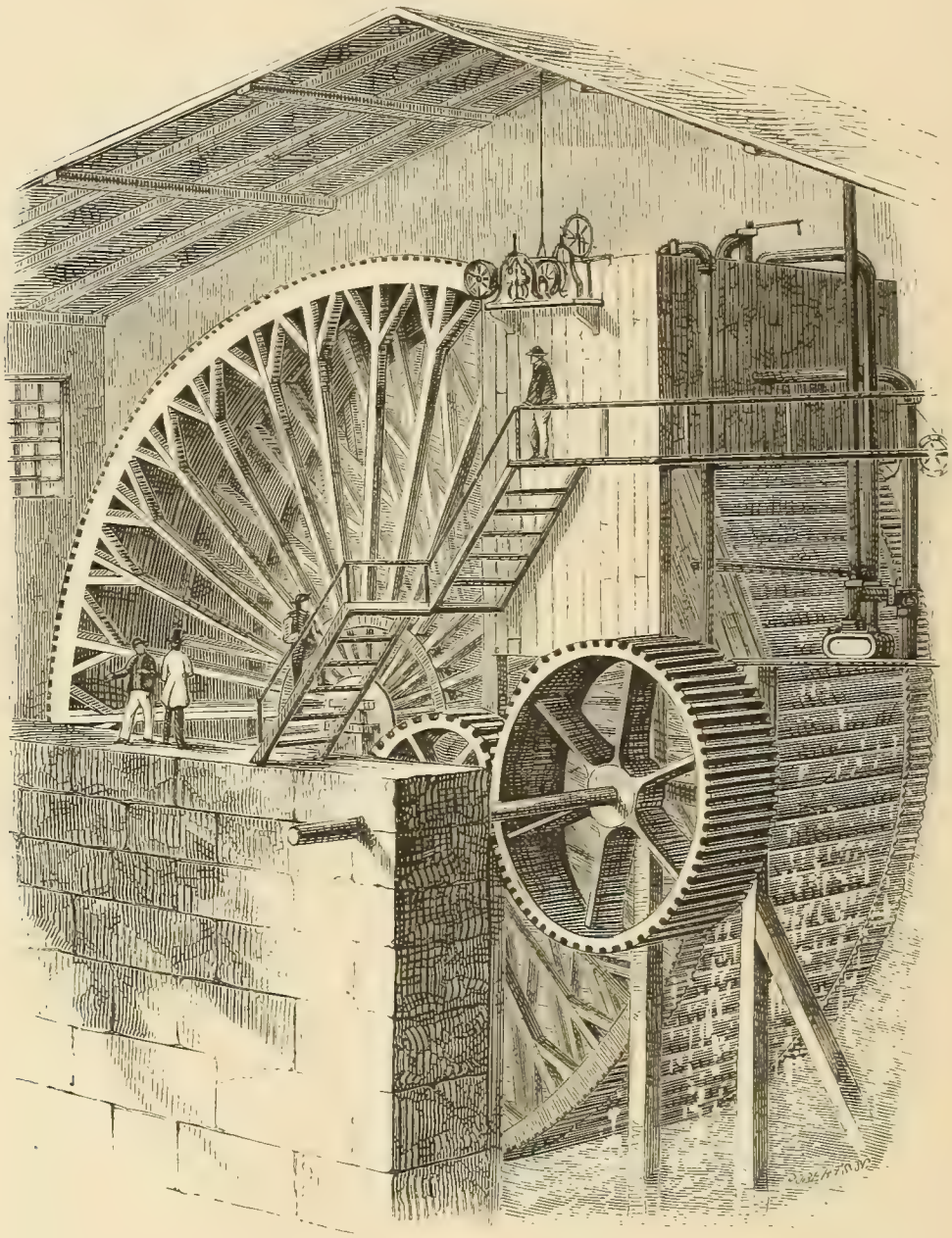


FIG. 33.—LARGE OVERSHOT WHEEL.

loss both above and below, say one-half of the depth of two buckets, equal to the depth of one bucket.

Vertical Wheels vs. Turbines.—Vertical wheels (that is, wheels with horizontal axes) generally cost more to erect than turbines, except for low falls. Vertical wheels are very much impeded by ice forming, while

turbines are not; back water interferes with them seriously, and they are more difficult to erect than turbines. In all wheels there is loss by reason of the space between the wheel and gate; some by friction in gate and buckets and journal friction.

The Largest Water-Wheel.—One of the largest water-wheels in the country is the overshot which runs the Cascade mill at Akron, Ohio. It is 30 feet diameter by 10 feet face; but one much larger is that shown in Fig. 33, and which is over 50 feet in diameter. This is used to drive the factory of the New York Belting and Packing Company, on the Potatook River. Both of these great wheels are now supplemented by steam.

Screw Flood Wheels.—The screw flood or spiral wheels are very little used. They are just like the propeller wheels of steamboats, except that they are stationary and the water moves; while in the steam propeller the water is comparatively at rest and the wheel advances with the vessel. They are best made of several detached blades or vanes, instead of a continuous screw. The more rapid the current the more obliquely the vanes must be set in the direction of the stream. For very slow currents they must be set nearly across the stream. They must have a mold-board twist, giving the inner end more obliquity than the outer. In many situations the power can be taken from them by an endless chain of open malleable iron links, which answers best for this slow, heavy motion. In winter in cold climates, however, this chain will give trouble by carrying up water and covering everything with ice. Where there is ice, then, it will be preferable to take the power off of the down stream end from a narrow-armed cog wheel. There must be a boom or breakwater up stream to protect it. These wheels are much in use in Holland. There was one upon the Genesee River, between Rochester and the Alleghanies, before the Genesee Canal was built. This wheel was about 9 feet long with a 15-inch shaft, the screw being of pieces extending out about 2 or 3 feet from the shaft and widest at the outer end; having a bar of iron twisted around the outer edge. The whole was inclosed in a box.

CHAPTER VI.

TURBINES.

Theory—Vertical Wheels vs. Turbines—Useful Effect—The Victor Wheel—Ordering Wheels—High Falls—Steps—Clogging—Variations of Power—Water-Wheel Governors.

Theory of the Turbine.—The essential parts of a turbine wheel are an axis, having attached to it two crowns, between which are equidistant curved vanes or buckets, against which the driving current is directed simultaneously at all points of the circumference by guide-blades not attached to the axis. The action of the water on any one bucket is repeated all around, and in analyzing the construction and operation of the wheel we may calculate as though there was only one bucket.

There are five general principles applicable to turbines of all kinds: 1. When a surface moves in a given direction under given pressures, the component pressures in all directions, except that of motion, are neutralized, either by reciprocal actions, or by fixed surfaces, which guide the moving surface. Therefore, in considering mechanical work done by given pressures acting upon moving surfaces, it is necessary to take into account those components only of the pressures which act in direction of the motion (friction being neglected). 2. In whatever direction a surface is moving with reference to the earth, if the fluid moves along this surface in a direction opposite to the motion of the surface and with a relative velocity equal to the velocity of the surface with reference to the earth, the fluid will be at rest with reference to the earth. 3. A fluid stream, striking a smooth surface at any angle whatever, is not reflected like a solid, but flows along the surface. *a.* If the surface is fixed, and the stream is confined in a channel of uniform dimensions before and after striking the surface, the velocity of the stream will remain unaltered (friction not being considered). *b.* If the surface is moving, the velocity under the same conditions after striking the surface will be the relative velocity of the surface and fluid before impact. If, for instance, a fluid jet impinges perpendicularly upon a plane surface moving with any velocity in the same direction, the relative velocity will be the difference of the two velocities, and this will be the velocity with which the stream will flow along the surface. This initial velocity gives rise to a pressure due to impulse, the direction of the pressure being always normal to the surface at the point of impact. 4. If the surface is curved the same phenomena occur, except that the relative velocity of the particle of steam is not entirely destroyed until it reaches a point at which it is moving at right angles to the direction

of the motion of the surface. 5. After the particle passes that point it flows along the curved surface without any further change of relative velocity, a change of curvature having no effect to change the velocity of flow relatively to surface.

The effect of reaction results from the action of the water while in contact with the bucket, after it has attained the speed of the bucket. It is measured by the product of the mass of water times the relative velocity imparted to the water in a direction opposite to the motion of the bucket times the velocity of the bucket.

Nearly all modern turbines may be classed in three types or their combinations—viz., outward flow, inward flow or centre vent, parallel flow. In all cases the fixed guides give the water a tangential whirl as it enters the wheel. Whatever motion the fluid has with reference to the earth, on leaving the vane, represents unutilized force. There is for every wheel a maximum velocity, beyond which there is little or no gain in going. Thus, in one case, increasing the wheel velocity from .48 to .68 of the velocity due to the fall affected the efficiency only 2 per cent. Nearly

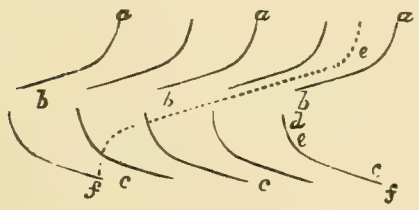


FIG. 34.

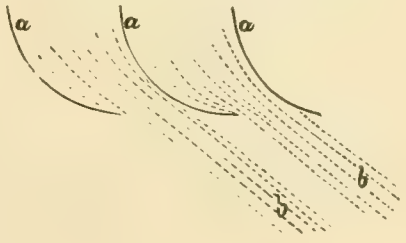


FIG. 35.

all of the theories of turbine construction which are going the rounds of text books are incorrect as far as applied to modern practice, and, in some respects, are quite the reverse of true. The effect of the water striking the curved vanes of a rotating wheel is due, according to the curve of the vanes, to either impulse or reaction, or to both. The effect due to impulse may be increased by the mass of water times, the velocity of the bucket times, the relative velocity of the fluid in the direction of motion of the bucket. The turbine differs from the vertical impulse wheel, in that the whole of the water in the turbine is acted upon by the water at the same time and continuously, and the water glides from the opposite edge to that at which it enters.

If the water passes through the chutes *a a a* (Fig. 34), it will pass into the space between them and the wheel *b*, and will be given a direction the same as that of the wheel, with a velocity of .7, and will issue out between the face *c c* in a contrary direction, with equal velocity as regards the wheel ; but, as the wheel is moving with the same velocity without actual velocity, the actual course of the water will be the dotted line *a c b f*. If the water passes through the face (Fig. 35), its direction on leaving is by that of the dotted lines *b b*; but if it passes through *a a a* (Fig. 36), its direction will have that of *b b b*, which will be a much greater change. If the face is formed like Fig. 37, with the top parts cycloidal and the bottom part tangential to the vextex of the cycloid, the greatest possible quantity of water will issue with the greatest possible change of velocity and direction.

The water discharged from a turbine in operation giving out its maximum effect leaves the short discharge-tube moving in the same rotary direction as the wheel, and with a velocity nearly equal to that due to the effective head multiplied by the coefficient of discharge for the chute openings and discharge orifices of the wheel. In some wheels the discharge openings of the wheel are larger than the chute openings of the case. In others, the discharge orifices are smaller than the chute openings. The discharging water from the turbine tends to spread horizontally from the moment it escapes from the short draught-tube, moving in curved lines towards the horizontal lines. Below the draught-tube there is a body of water having a movement of rotation, from one side of which there is a volume of water throwing off tangently but slightly crosswise of the tail-race if closed. The quantity of water discharged through the flume opening of a wheel going under an effective head, when the chute openings are fully open and the wheel is removed, is about the same as that discharged when the wheel is in the case with chutes fully open and doing its best work under the same effective head. The faster a turbine revolves, the less it will realize of the head due to the hydrostatic pressure, and the slower it revolves the more it will realize.

A question is sometimes put as to whether a turbine wheel can run faster

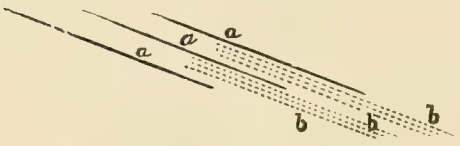


FIG. 36.

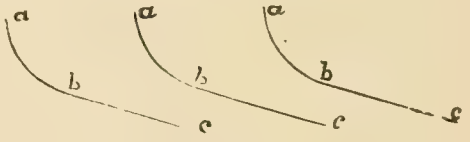


FIG. 37.

than the water which drives it. It is apparently a paradox if it is the case. but none the less impossible. Water tends to press on all sides alike. If all of the outlets of a wheel should be closed, it would not move, being held *in equilibrio.* If the wheel moves with the same velocity as the issuing water, no work will be done. If the wheel moves with less velocity than the effluent water, work will be done. To produce a maximum effect, the wheel should move just one-half as fast as the water that issues from the wheel, The velocity of water issuing from a head will be as the square root of the height, and will be something near .7 that due to the whole head. If a reaction wheel, moving with a velocity of .7 that due to the head, has the water let on it in the direction of its motion through a chute or chutes equal to that of all the issues of the wheel, the velocity of the water and of the wheel will each equal .7 and the pressure of the water on the wheel will be equal to .5 the whole head. The water will act upon the wheel just as if both were at rest, and will, therefore, issue from the wheel with a velocity due to one-half the head, that is, .7 as relates to the wheel; but, as the wheel moves with the same velocity in the same direction, the water leaves the wheel without actual velocity. As the wheel moves with a velocity equal to that of the effluent water, and with a force equal to the weight of one-half the whole column of water, the duty is 50 per cent., or double what it would have been had it been let on without a motion in the direction of the wheel. Water issuing from an aperture in a thin plate will

have a discharge equal to .62 that assigned by theory. If we apply to the aperture a tube of equal size throughout, and with a length equal to twice its diameter, the discharge will be .80. But, if we fix a cone-shaped tube inside of the vessel, the discharge will be very nearly that due to theory.

Vertical Wheels vs. Turbines.—A gentleman of ample experience remarks: "The first requisite in a good mill is good motive power, and among all hydraulic motors yet discovered none can compete with a good turbine, for the following leading reasons: The turbine is not affected by ice; it is not affected by back water, save the loss of power due to the loss of head; it is much cheaper in first cost; it is more cheaply and easily transported and erected; it is suited for all heads and all locations; and above all,

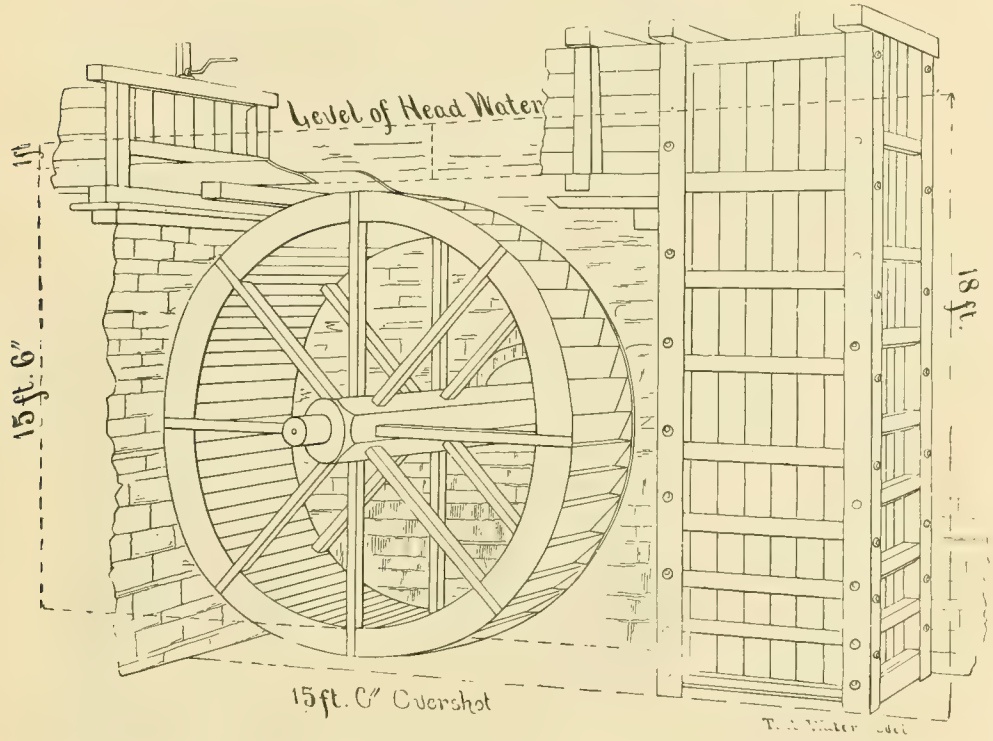


FIG. 38.

it is more economical in the use of water, for its high velocity dispenses with the cumbrous double gearing which is absolutely necessary with under or over shot wheels, with which, as experience has abundantly proved, about one-third of the power of the water is expended in simply obtaining velocity, or overcoming the inertia of matter." Turbine wheels require a less height of stone foundation than other wheels. The overshot wheel splashes about, and causes rot unless the wood work is quite high; but there are cases where it is not convenient to have the millstones above their splash level, as for instance where it is desirable or necessary to have the stone floor near the road level for teams.

Overshot vs. Turbine.—Fig. 38 is intended to show why an overshot wheel will not always yield the full power of the water. It shows an overshot wheel and the flume of a turbine to do the same work, the head and fall in both cases being 18 feet (a fair average). Of this it is customary to

allow 2 feet for head above the overshot, and 6 inches to prevent the wheel wading in tail water, limiting the diameter of the wheel to 15½ feet. As

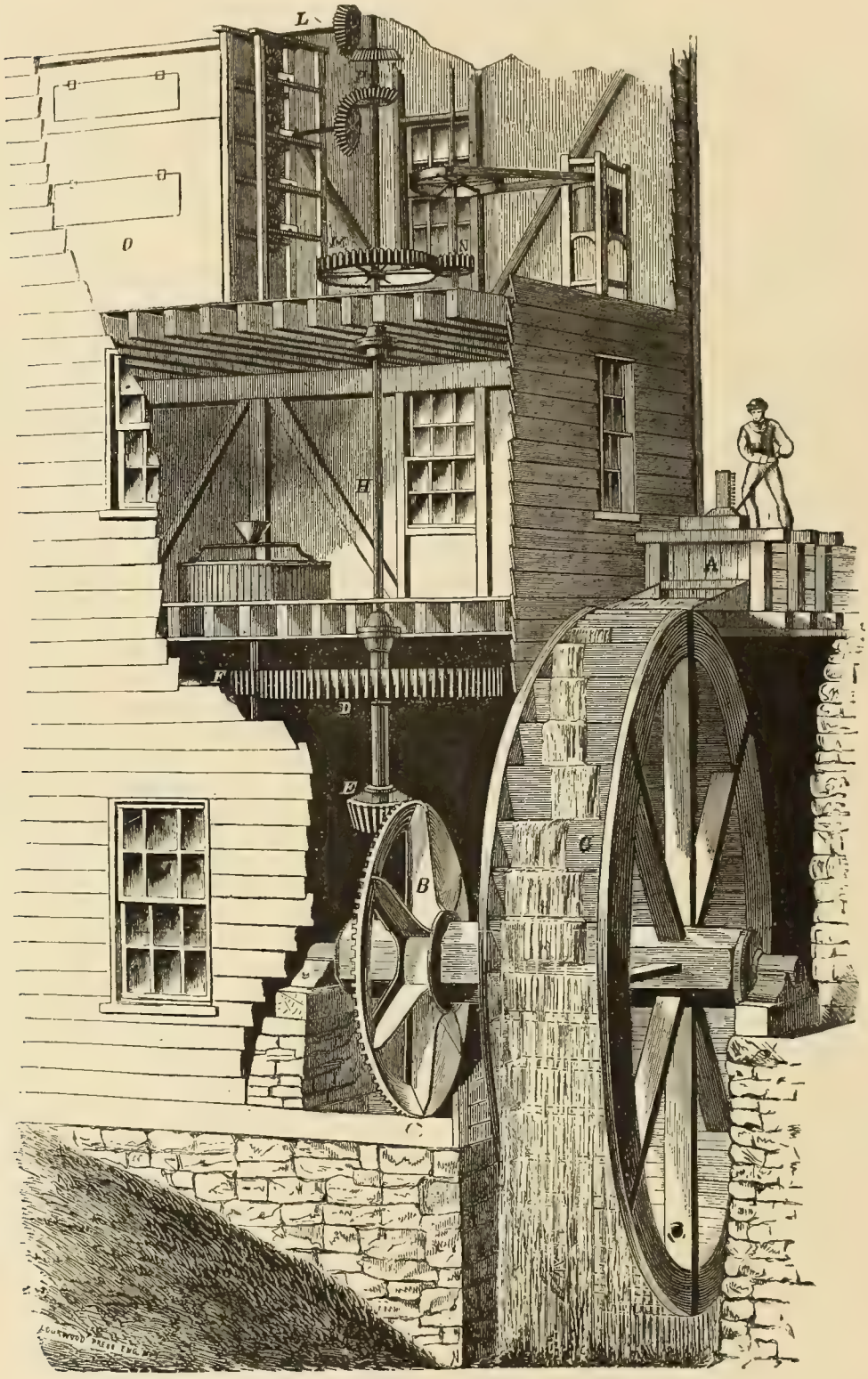


FIG. 39.—OVERSHOT.

the wheel begins to empty at some distance above the level of the water in the tail race we may take off another foot of fall as lost, leaving 14½ feet,

or only about 80 per cent. of the whole fall used. The turbine being at the bottom of the flume uses every inch of head and fall.

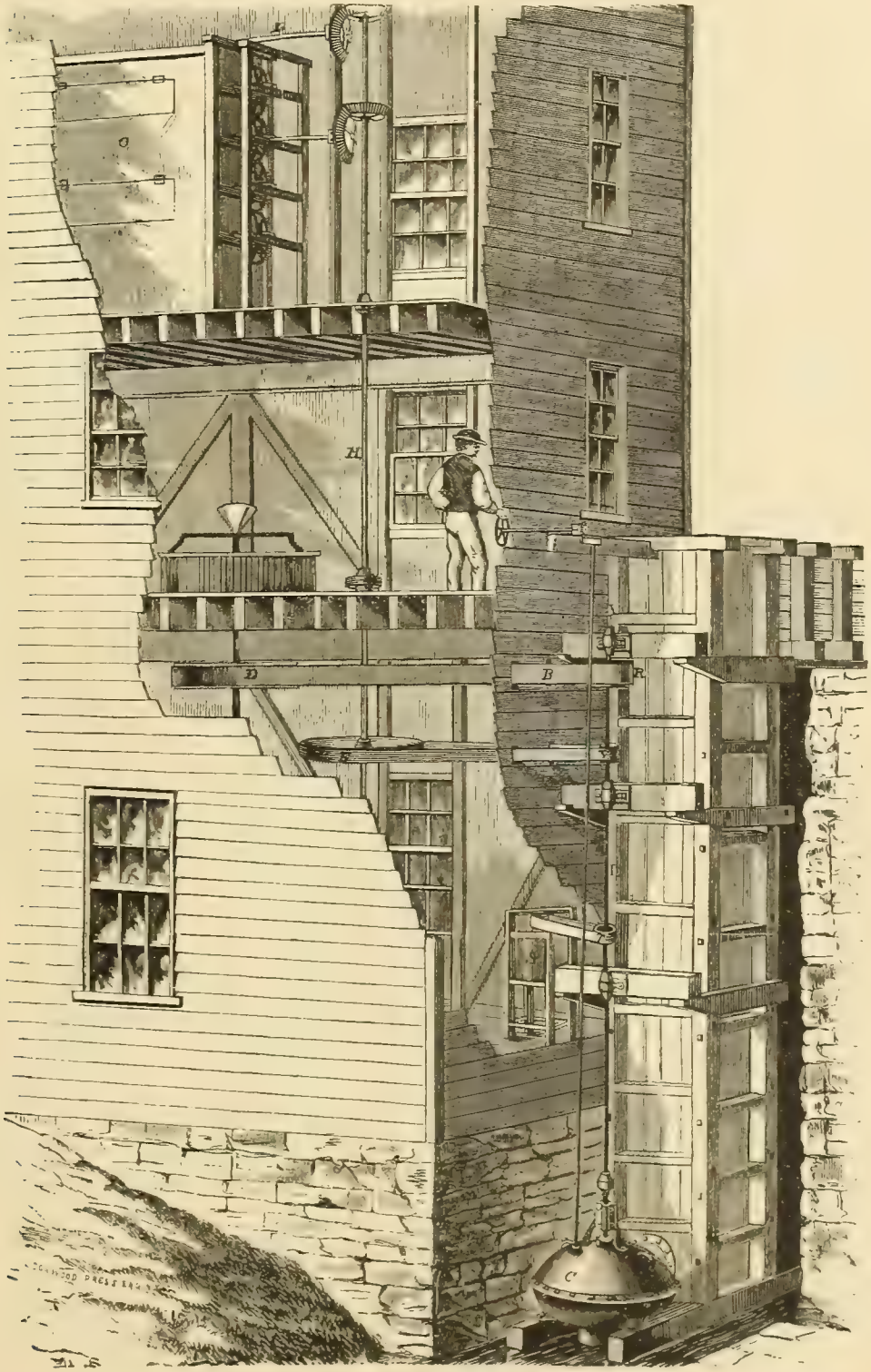


FIG. 40.—TURBINE.

Figs. 39 and 40 are intended to show the advantage of a turbine, for high falls, over an overshot wheel. The overshot shown is of 22 feet diam-

eter by 3 feet face, to work under 24 feet head and fall. The bevel wheel B is 12 feet diameter; spur wheel D is 9 feet. The upright, running only 20 turns per minute, must be very heavy—in this case 8 inches in diameter. The shaft H must be at least 4 inches in diameter. It will be seen that all of the parts are very heavy and that friction is necessarily very great; while the cost is excessive. The other cut shows an 11½-inch turbine, which will give more power than the 22-foot overshot. Instead of the 2-foot shaft of the overshot, or an iron shaft of 10 inches, there is simply a 1¾-inch wrought-iron shaft; while there is needed only a 10-inch iron pulley weighing 30 pounds, from which the belt runs directly to the buhrs. Instead of the 4 to 8 inch shaft H, there is a light 1½-inch shaft. Instead of gearing up for the speed of the smutter, by a spur wheel M, and the pinion N, and pulley, none of this gearing is required, as the wheel makes nearly 600 turns.

Useful Effect.—A good turbine will develop over 80 per cent. of the useful effect of the water; but the fancy tests published are generally made with special wheels with Russia iron or graphited guiding surfaces, and under exceptional conditions, during a short run only. The following tests of the Victor wheel were made in the Holyoke flume by James Emerson, and are stated to be made on regular-made wheels taken from stock:

Size of Wheel and Date of Test.	Head in Feet.	Revolutions per Minute.	Horse-Powers.	Cubic Feet of Water.	Percentage Useful Effect.
25-inch Victor turbine.....	17.79	205.5	67.72	2362.72	.8530
Tested October 28, 1878..	17.96	209.	68.62	2356.54	.8584
30-inch Victor turbine.....	11.65	144.5	52.54	2751.87	.8676
Tested October 29, 1878..	11.66	147.5	51.96	2755.09	.8564
15-inch Victor turbine.....	18.34	323.	29.36	973.75	.8705
Tested March 26, 1878...	18.10	321.5	29.22	970.39	.8808
15-inch Victor turbine.....	18.06	368.	30.17	990.19	.8932
Tested August 23, 1879...	18.08	355.	30.12	996.83	.8849
20-inch Victor turbine.....	18.22	286.	48.75	1660.17	.8532
Tested May 21, 1880.....	18.23	275.	48.75	1660.17	.8528
	18.21	269.5	49.00	1671.57	.8522
			Full Gate.		
15-inch Victor turbine.....	17.97	348.5	30.62	974.47	.9258
Tested April 9, 1880.....	17.98	347.5	30.53	972.80	.9242
	17.98	337.5	30.66	977.81	.9234
	17.98	323.	30.36	981.15	.9111
			Part'l Gate.*		
	17.99	334.	29.35	971.13	.8896
	18.02	331.5	26.11	901.88	.8506
	18.09	339.5	23.14	808.53	.8376
	18.20	339.	17.97	695.06	.7538
	18.38	334.	10.62	482.59	.6345

*Part gate does not mean any fixed position of the gate wheel, nor does it refer to the amount of gate opening, but to the amount of water used by the wheel as determined by measurement on a weir.

The makers state that all of these wheels were plain cast-iron wheels, and were tested for purchasers, except the last named wheel, which was furnished to the Holyoke Water Power Company for the purpose of making some experiments on gears, belts, draft tubes, &c. It will be observed that steady improvement was made subsequent to the date of the first test.

A 17½-inch wheel, tested by C. Herschel, engineer for the Holyoke Water Power Company, on August 5, 1880, yielded .896 per cent. useful effect.

Machines furnished by many builders specially for competitive test do not give the same results as those taken from stock; and an excellent way for the buyer to secure himself against loss or imposition, in cases of machines which have guarantees published, is to stipulate that the purchased machines shall under the same conditions give the same duty or no pay. It is useless to buy a turbine which will give a duty of 85 per cent. or over for one day only. Such tests are of little value to any one. Some wheels, giving excellent results under test conditions, will go to pieces with the rough usage of regular work.

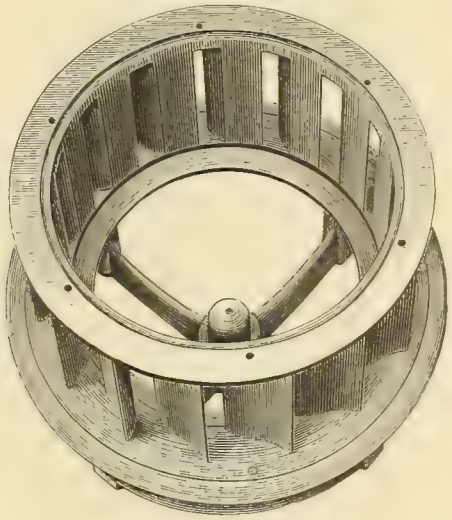


FIG. 41.—OUTER CHUTE CASE (VICTOR WHEEL).

The only safety in such a matter is to buy only wheels of high reputation for durability and long continued efficiency. There are some wheels which are extremely bad about burning out their steps. A good plan for testing turbines would be to fix the standard of speed, at which the wheel shall run while at labor, at the velocity at which it produced the best results when working under three-quarters gate (instead of at full gate as is customary), especially if the wheel is to be run mainly at partial gate, for the wheel when running at partial gate requires a little slower motion to develop its best results than when running at full gate. This is in any case true of wheels of large capacity.

The Victor Turbine.—In setting forth the advantages of the Victor wheel and its claims upon public confidence, the makers state that all of the work in fitting it up is performed by machinery, every separate part being fitted to a standard gauge. By this means duplicates that will fit can be furnished at any time. Following is a description of this wheel :

Fig. 41 is the outer chute case and cylinder, with the bridgetree and wood step which support the wheel, in position. The case is one casting, and after receiving the bridgetree, which is secured by set screws as shown,

is placed upon a horizontal boring mill, and is bored out to receive the register gate (Fig. 42), which revolves within it. It has a projecting flange, which rests upon the floor of the penstock, and this flange is faced off true, at a right angle with the wheel shaft, so as to insure the wheels setting plumb, provided the floor of the penstock is level.

Fig. 42 illustrates the inside register gate, which is cast in one piece, with fixed water ways corresponding with the chutes in the outer case—the two combined forming one duplex chute. This gate is bored out to receive the

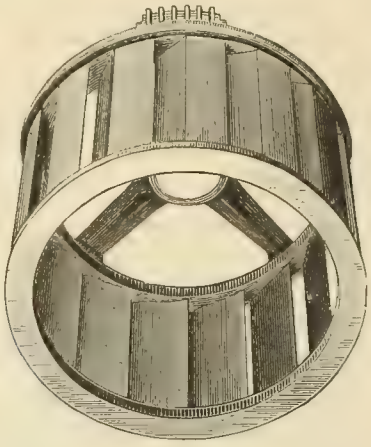


FIG. 42.—REGISTER GATE.

wheel and is turned off to fit the outer case, within which it revolves, and is moved, for the purpose of admitting and shutting off the water, by means of a segment and pinion. The movement of this register gate regulates the amount of water supplied to the wheel, and secures an equal and uniform delivery on all parts of the wheel, without changing the direction of the current or the relative angle of the stream and the face of the bucket, or greatly checking the velocity of the water admitted to the wheel. There is a four-armed spider, attached to the gate as shown in Fig. 42, the hub of which is bored out to fit accurately upon the lower end of the pedestal,

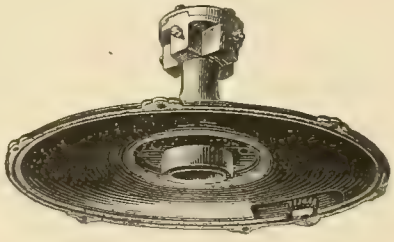


FIG. 43.—TOP OF WHEEL CASE.

which projects beneath the top of wheel-case and forms a journal-bearing, as shown in Fig. 43. The makers state that this improvement in its practical workings is of great value. It enables them to fit the gate so very close that it cannot leak, and yet have it work easily; it strengthens the gate, holds it rigidly to shape, reduces the friction in moving it to its minimum, and as nearly as possible obviates the objection hitherto urged against a register gate. The merits of this gate, composed of one single casting, instead of a complication of butterflies, rings, rods, and bolts, will be apparent. Fig. 43 represents the

top of the wheel case with the pedestal attached, through which the wheel shaft passes. The projection of this pedestal underneath the top, and passing through the hub of the gate-spider, forms a feature of lately patented improvements, as previously mentioned, and is so clearly shown by the artist as to be readily understood.

As will be seen, this top is composed of a single strong casting. It extends over the register gate, and is fastened by set screws to the outer chute case. This arrangement protects the gate from vertical pressure of the column of water and renders its movement very easy. This simple arrangement also greatly facilitates the erection of wheels, or obtaining access to them in case of accident, as by simply removing the set screws the top becomes detached.

The pinion and segment by which the gate is operated are housed to protect them from breakage by foreign substances getting in between the teeth. The cap of this housing, as shown in Fig. 45, may be detached by removing

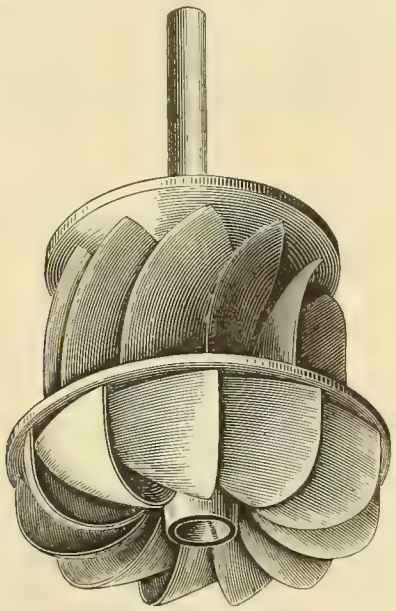


FIG. 44.—VICTOR WHEEL REMOVED FROM ITS CASE.

two set screws. This protection of the pinion and segment is of great value. The pedestal, which surmounts the wheel case, after being faced off true, is fastened to the top or crown plate by set screws. The seat below the follower blocks insures a rigid upper bearing for the wheel shaft, independent of the follower blocks and, in connection with the arrangement of the bridgetree that holds the step for the wheel shaft, secures steadiness of motion, low friction, and strength and durability.

Fig. 44 shows the Victor wheel on its shaft removed from the chute case. The wheel presents some decidedly novel features. It receives the water upon the outside and discharges it downward and outward, the lines of discharge occupying the entire diameter of the lower portion of the wheel, excepting the space filled by the lower end of the shaft.

Fig. 45 shows the wheel as it appears when shipped to customers, ready to set in the flume. As will be observed, the chute case and gate are substantially the same in construction and operation as those used for several years past in the " Eclipse " wheel.

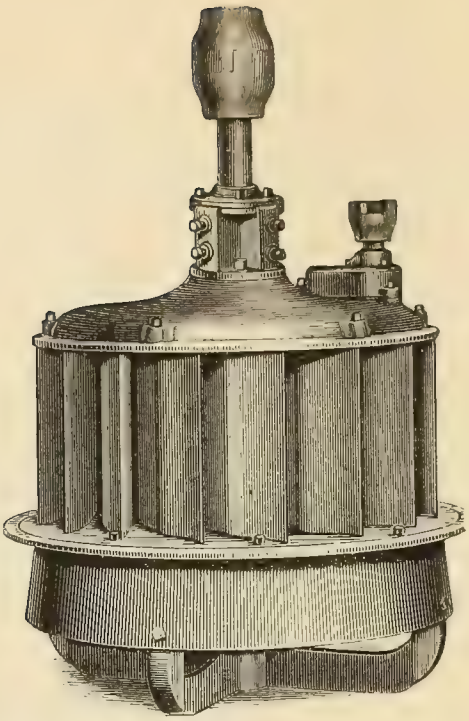


FIG. 45.—VICTOR WHEEL AND CASE COMPLETE.

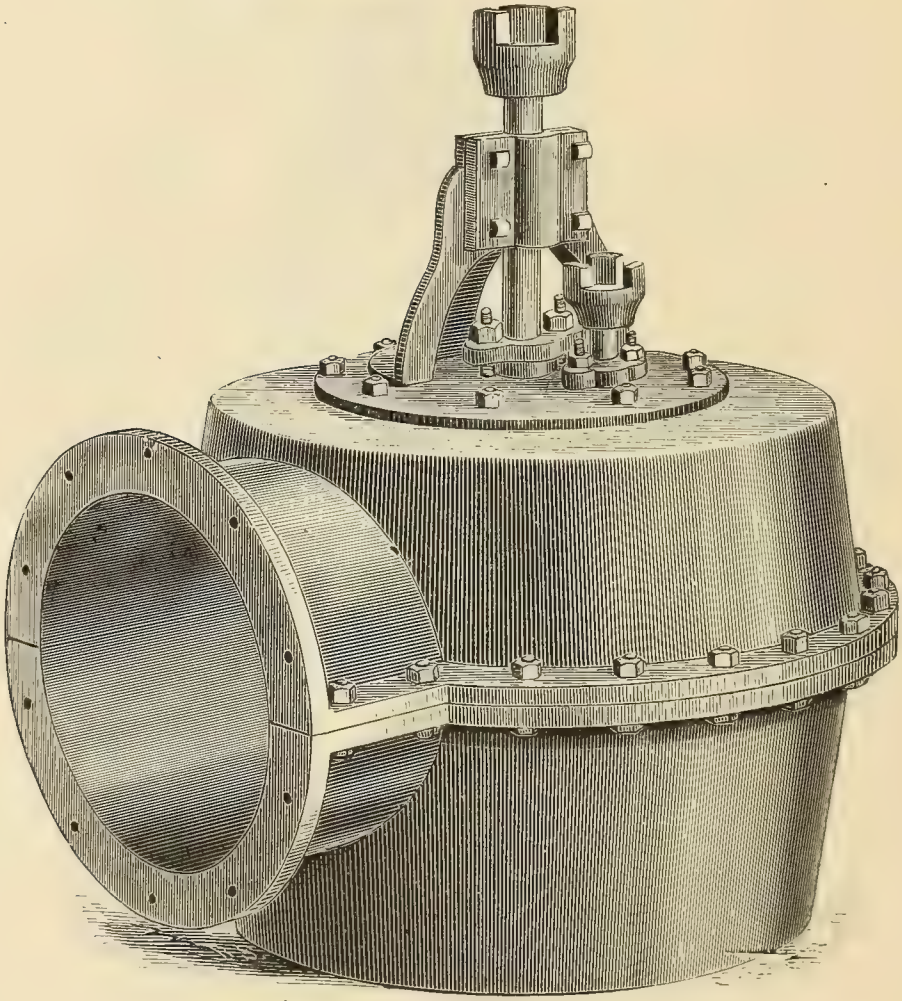


FIG. 46.—IRON PENSTOCK.

The prices of the Victor turbines are given as follows: *

6 inch wheel,	made of	brass,	. . . .	Price	$200
8 "	"	"	"	"	215
10 "	"	"	"	"	225
12 "	"	"	iron and brass, . .	"	240
15 "	"	"	iron, ...	"	250
17½ "	"	"	"	"	290
20 "	"	"	"	"	325
25 "	"	"	"	"	435
30 "	"	"	"	"	550
35 "	"	"	"	"	700
40 "	"	"	"	"	875
44 "	"	"	"	"	1100
48 "	"	"	"	"	1300

The above price list is for wheels complete, ready to set in the penstock, delivered free on board cars at Dayton, and includes hand-wheel, gears, and pawl and ratchet for operating the gate, with short pieces of shafting fitted in each. In ordering wheels state whether they are to run with the sun, or against the sun.

Appended is a table of dimensions of the "Victor" turbine. The lettered columns in table correspond with the dotted lines in Fig. 47.

Size of Wheel.	A	B	C	D	E	F	K	Approximate Weight of Wheel, Complete.
	Diameter of Cylinder Passing Through Floor of Flume.	Diameter of Entire Wheel Case.	Internal Diameter of Flume.	Length of Shaft from Flange Resting on Floor of Flume to Centre of Coupling.	Diameter of Bore of Upper Half of Coupling.	Length of Cylinder Passing Through Floor of Flume.	Depth of Pit from End of Cylinder to Bottom of Wheel Pit.	
Inches.	Inches.	Inches.	Feet.	Inches.	Inches.	Inches.		Lbs.
6	9¾	12¾	2	15	1 5/16	2⅛		
8	13½	16	2½	18	1 3/16	2½		
10	16	18	3	21	1 3/4	3¾		
12	20¾	18	3½	25	1 5/8	4⅜		
15	23	25¼	4	29½	1 15/16	5¼		715
17½	26	30	5	32	2 1/4	6		925
20	30	32	6	33	2 5/16	6¾		1175
25	35	40	6½	40	3 3/16	7½		2100
30	40½	46	8	47¾	3 7/8	8½	From 2 to 6 feet deep, according to size of wheel and quantity of water used.	3100
35	46	51	9	55½	4 3/8	11		4500
40	52	57	10	59¾	4 7/8	12		6450
44	56	61	11	63	5 3/8	12¾		7850
48	60	66	12	65½	5 7/8	13½		9425

Column A also indicates the proper size of hole to be cut in floor of flume to receive the wheel.

* August 1, 1881.

Correspondence indicates a frequent misapprehension of the meaning of the term "square inches of water vented." Some think that in a wheel said to use "100 square inches of water," it is meant that the entire area of the chute apertures measures 100 square inches; others think the meaning to be that the entire area of the discharge apertures is 100 square inches. Neither

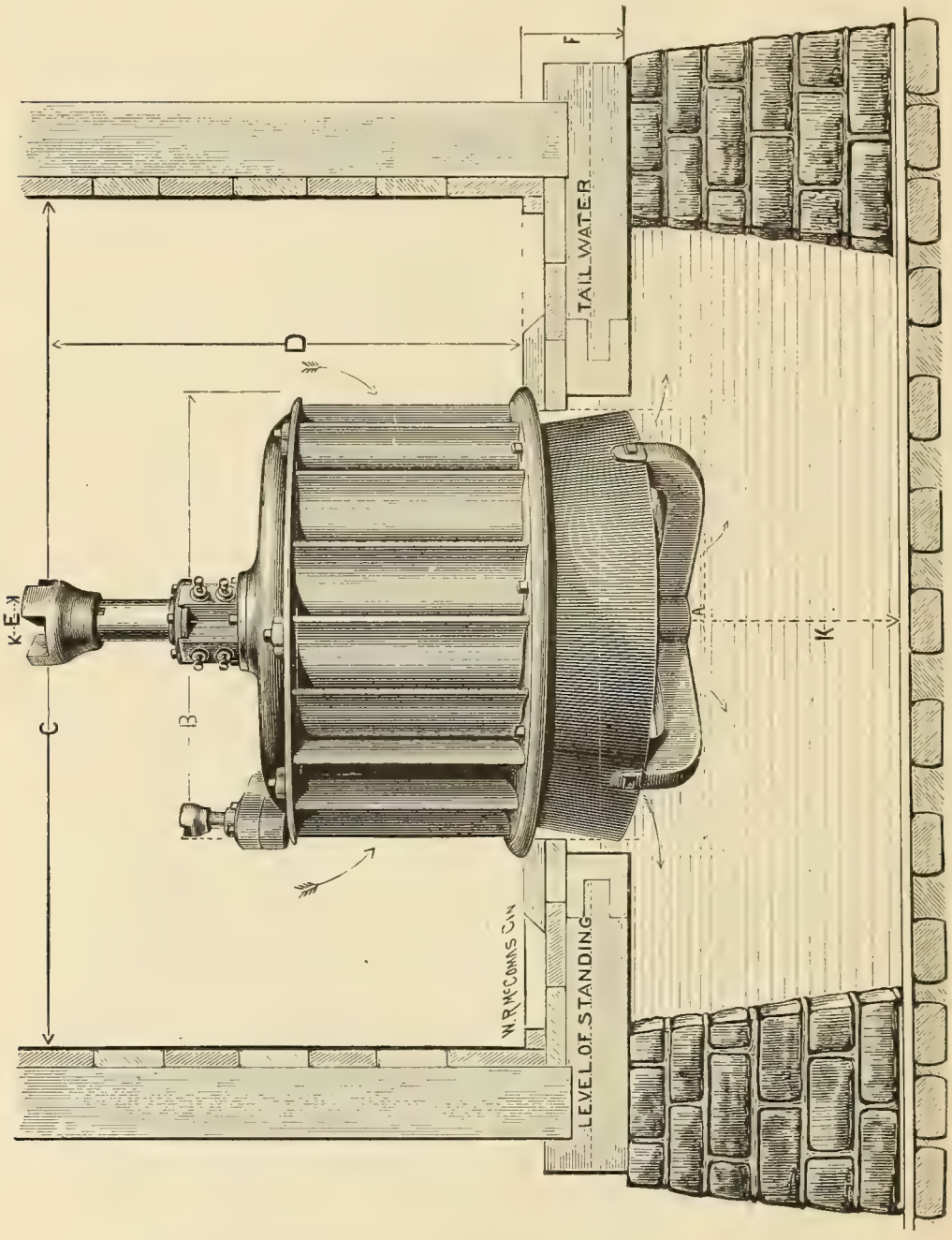


FIG. 47.—VICTOR WHEEL SET IN ORDINARY FLUME.

of these views is correct; but the meaning is that the theoretical discharge under any head, due to an aperture measuring 100 square inches in cross section, would equal the actual discharge of the wheel under the same head. A "square inch of water" means a stream exactly one inch square and equal in length to the theoretical velocity in feet per second due to the head from

under which it issues. For a head of four feet this length would be 16.04 feet per second; for a head of ten feet 25.36 feet per second. This velocity in feet per second, and the equivalent of a "square inch of water" expressed in cubic feet per minute, under heads of from 1 to 40 feet, appear in the table:

6	in. wheel uses	12	square ins. water.				25	in. wheel uses	180	square ins. water.		
8	"	"	19	"	"	"	30	"	"	248	"	"	"
10	"	"	33	"	"	"	35	"	"	383	"	"	"
12	"	"	50	"	"	"	40	"	"	459	"	"	"
15	"	"	73	"	"	"	44	"	"	521	"	"	"
17½	"	"	96	"	"	"	48	"	"	614	"	"	"
20	"	"	119	"	"	"							

VELOCITY AND DISCHARGE OF WATER THROUGH SUBMERGED ORIFICES.

Table showing the theoretical spouting velocity of water in feet per second and number of cubic feet discharged per minute, through an orifice of one inch area, under different heads, from one to forty feet.

(Calculated from Francis' Formulas.)

Head, in Feet.	Velocity per Second, in Feet.	Cubic Feet per Minute, Area of Orifice One Inch.	Head, in Feet.	Velocity per Second, in Feet.	Cubic Feet per Minute, Area of Orifice One Inch.	Head, in Feet.	Velocity per Second, in Feet.	Cubic Feet per Minute, Area of Orifice One Inch.	Head, in Feet.	Velocity per Second, in Feet.	Cubic Feet per Minute, Area of Orifice One Inch.
1	8.02	3.34	11	26.50	11.08	21	36.75	15.31	31	44.65	18.60
2	11.34	4.73	12	27.78	11.57	22	37.62	15.66	32	45.37	18.90
3	13.89	5.78	13	28.91	12.05	23	38.46	16.02	33	46.07	19.20
4	16.04	6.68	14	30.00	12.49	24	39.29	16.36	34	46.76	19.48
5	17.93	7.47	15	31.06	12.94	25	40.10	16.71	35	47.45	19.76
6	19.64	8.18	16	32.08	13.36	26	40.89	17.04	36	48.12	20.05
7	21.22	8.84	17	33.06	13.77	27	41.67	17.36	37	48.78	20.33
8	22.68	9.45	18	34.02	14.18	28	42.43	17.68	38	49.44	20.60
9	24.06	10.02	19	34.96	14.57	29	43.19	17.98	39	50.08	20.87
10	25.36	10.57	20	35.87	14.94	30	43.93	18.30	40	50.72	21.13

The Victor is a flume wheel, constructed to rest, by the flange of its case or stationary part, upon the floor of the flume, over an aperture in the floor through which the water is discharged. No particular form of flume is required, but it is necessary that the foundations be made perfectly secure to avoid settling or getting out of level, and its strength in all directions should be sufficient to sustain the pressure of water under any circumstances. The floor timbers should be placed in the direction of the current, with their upper surface at the height of standing tail water. The pit under the wheel should not be less than two feet below the floor timbers, and from three to six feet for large wheels. This pit should be extended out into the tail-race

its full width and depth for several feet beyond the outside of the penstock, and then gradually sloped upward to the general level of the bottom of the tail-race. Too much importance cannot be attached to this matter of providing ample space for the wheel to discharge into; for, if there is not sufficient space in under the wheel to admit of the water's passing away from the wheel quietly and easily, it will react upon the wheel and seriously interfere with its performance. To ascertain the requisite size of flumes and tail-races, use the following simple rule. The makers' tables of power, etc., will indicate the proper size of wheel to produce the required power and also the number of cubic feet of water the wheel will discharge per minute. Divide the number of cubic feet stated in the tables by 85, and the quotient will be the area in square feet required in the cross section of the head or tail-race for every wheel used. That is to say, for every 85 cubic feet of water used by the wheel or wheels per minute there should be one square foot in cross section of all the water passages leading to and from the wheel, including of course the opening under the penstock, through which the water passes after leaving the wheel. The pit into which the wheel discharges must never be less than two feet deep for small wheels, and increased to three, four, five and six feet in depth for larger wheels, according to their size, and of sufficient width to produce the area in cross section mentioned in the above rule. Larger water courses than indicated by the above rule are not objectionable, but desirable; for, the nearer a state of rest the water can be brought to before entering and after leaving the wheel, the better will be the results obtained. In improving a water power, properly constructed water courses will amply repay the labor and money expended upon them, and are essential to the proper working of any wheel.

Sometimes in adapting wheels to very high heads, to avoid an excessive length of shaft on the wheel, and to otherwise conform to the peculiar location, it becomes necessary to set the wheel at some distance above tail water, and conduct the water away from the wheel through a draft-tube. The same depth of pit and area of discharge are required where a draft-tube is used as would be were the wheel set at the bottom of the fall. Theoretically, draft-tubes may be used of any length up to thirty-three feet, but practically it is unadvisable to use draft-tubes exceeding twenty feet in length, because of the difficulty in making and keeping them perfectly air tight; and if the draft-tube leaks air at all, the vacuum is imperfect, and loss of power, due to the loss of head, is the result. A draft-tube, if used, must be of sufficient internal diameter to receive the cylinder of the wheel case. If constructed of wood, it should extend up through the opening made in the floor of the penstock, flush with the face of the cants upon which the wheel case rests, and be firmly secured to the penstock by spikes or screws, and be securely banded at frequent intervals with iron hoops. If constructed of iron, which is far preferable to wood, the ring or flange to which the tube is riveted should be faced off true, and let into the cants, so as to form a perfect joint with the flange of wheel case. As a rule on all falls of moderate height, the wheel should be set at the bottom of the fall. But in all cases where a draft-tube is used, it is best to have one made of boiler iron, so as to secure durability and tightness.

Ordering Wheels.—In asking about a wheel to do a certain amount of work some merely say, "I have so many feet head," saying not a word about the quantity of water. Some say "I have so many cubic feet of water per minute," and do not give the head. Others ask, "With what size wheels can I grind so many bushels per hour?"

Now in ordering a wheel, or in asking for information, the following data should be given: Head of water when at rest, or the vertical distance from the surface of the head water to that of the tail water. If there is only a small supply, state what is the most that can be relied upon, as measured and calculated from the depth and width of flow over a properly constructed weir board. If there has been an overshot, this information may be got at by knowing how wide the wheel was, and how much the gate was raised to let the water on to it, and how deep the water was above the gate opening in the fore-bay. If there is plenty of water, state width and depth of the stream and speed in feet per minute of a board floating on its surface in the middle. If there is a turbine or a reaction wheel, already running, how many square inches of opening, and how many hours per day the stream will supply it. What kind of machinery is to be run (as full details as possible). If it is for corn or wheat; whether an old or new building and old or new process, buhr or roller. Size and number of buhrs and of rolls; how many bushels of grain each is grinding per hour; how many hours per day, and whether you wish to grind more. State whether or not all are to be running at once. If all are not to be running at once, how many are to be; speed of the main hue and shafting and if upright or horizontal. If the power is to be taken off above the level of the head of the water, the distance from the head of the water level to the level of the bed of the stones should be given. If the power is to be taken off below the head water level, by using a Decker flume, give the distance from the centre of the horizontal power shaft below the head water (or the distance above the tail water) when at rest. When there are many connecting gears, state whether spur or bevel, and the number of cogs, width or face of drivers on the pinions. State whether the turbine is to run in the same direction as the hands of a watch, or in the opposite direction.

High Falls.—The turbine of St. Blasien has 350 feet fall, and gives 73 horse-powers. And the double turbine at Saltillo has 160 feet fall, and produces 125 horse-powers from 1850 revolutions of wheels 11 inches in diameter.

About the only trouble with turbines is burning out steps. The step is generally made of lignumvitæ, but any hard wood will do to replace it if worn. Apple is good. The form of the step is generally very bad. In all cases there should be some way of insuring that the step shall be kept supplied with water to prevent heating and burning out. Every now and then some one writes to the papers or consults an expert to know why his turbine step burns down; or if he knows why, he wants to know what will stop it. The wood steps of turbines burn down because there is absolute contact between the rubbing surfaces. One remedy proposed is to have creases cut in the step and the concave, through which creases water may circulate. Care should be taken that the heart of the wood comes in the centre of the step, to insure even wear.

Clogging.—There are some turbines which will choke up with bark, leaves, or even coarse sawdust, and must be cleaned out at certain times of the day. In some places eels give a great deal of trouble in their periodical migrations down stream, in the fall. Eels give trouble because they can glide through most racks but cannot go through the wheels. Muskrats, which are such nuisances, for many other reasons, to those using water power, cannot be kept out of the wheel by a rack, as they climb over it or even force their way through by bending the bars.

Variations of Power.—There are two ways of overcoming the variations in resistance and in the head and height of water. The first is to have one or more turbines connected to the general shaft, each one or more of which can be detached at will. The second is the opening and closing of gates.

Whether the mill is driven by steam or by water there will be a tendency toward variation of speed caused either by increase of force in the motive power, by decrease in the load upon the machinery driven, by throwing on or off one or more machines, by the breaking of a belt, gear, or shaft, or the loosening of a shaft coupling. If the motor is properly regulated, such tendency to change of speed should be noticed at once by the governor; and the more sensitive and powerful the governor is, the more evenly the machine will keep on running. With unsteady water power, millstones are apt to jump with light feed, although they will run steady with heavy feed. This trouble is aggravated if the mill is geared too high.

Water-Wheel Governor.—To be of service, a water-wheel governor should be of sufficient strength to operate the gate of any of the ordinary turbines on the market; it should be durable, compact, and above all things should not "dance," but give a regulation at once without at first reducing the speed too low and then regoverning to too high a speed.

A water-wheel governor manufactured by A. W. Woodward, Rockford, Ill., is shown in Fig. 48. In this governor the pulley is 10 inches in diameter, 3-inch face, makes 135 revolutions per minute and should be driven with a $2\frac{1}{2}$-inch belt. The shaft g, which runs continually, has a slight lateral movement as the balls rise and fall, being connected with the same by means of the grooved collar b, rock-shaft e, and bent lever o. The lever o is made with a spring joint which opens when more pressure is applied than is necessary for opening the gate. The beveled pulleys a, a' run loose on the shaft g and have pinions d attached to their hubs and are held in place by means of grooves at the end of the hub. By means of a screw x the position of the pulley a' can be changed, giving any required distance between a and a', making the governor more or less sensitive as required. Inside of the pulleys a and a' is a pulley f beveled on the rim to the same angle with a and a', covered with leather, and turned to a perfect fit with a and a'; this pulley f is fastened to the shaft g and runs continuously. A stop-nut s moves back and forth on the shaft m as the governor opens and shuts the gate; a lever n on the rock shaft is made to adjust by means of a set screw so that the nut s will strike it when the gate is full open, preventing the pulley f from coming in contact with the pulley a', the spring joint in the lever allow-

ing it to do so without interfering with the movement of the balls. At a point shown by a dot on the lever, *o*, is a pin which projects so that the nut *s* strikes it when the governor has closed the gate sufficiently to allow the wheel to run nearly to speed with no machinery attached. This movement destroys the connection of *f* with *a* but allows the nut to travel along the shaft until the gate is closed, which must be done by hand. The object of this stop, when used at part gate, is to obviate a difficulty where a large amount of machinery is thrown off at once, causing the wheel to run at a high rate of speed and continuing to run above the speed of its own momentum after a sufficient amount of water has been shut off. It often happens in such cases, where the governor is allowed to shut off water until the speed is

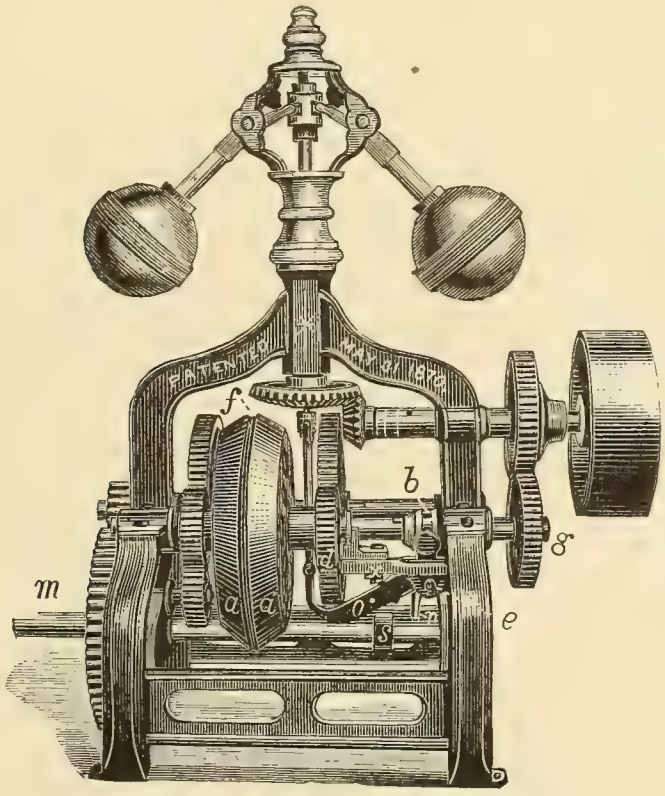


FIG. 48.—FRICTION WATER-WHEEL GOVERNOR.

slackened, that the machinery is again thrown on at the instant when there is not enough on the wheel to run it to speed, let alone the additional power required to start the machinery. It also has a brake to hold the gate where it is inclined to close itself, so constructed that the greatest amount of friction is brought to bear when the gate is being closed, and less when it is being opened.

The advantages claimed for the Woodward governor are: 1. That the movement is continuous and not intermittent, and allows the gate to be moved to position in much less time with a slower movement than that given where pawls are used. 2. It is sensitive and requires only a slight change in the position of the balls for the governor to act on the gate. Of the total weight of the balls, two to five ounces thrown on the friction wheels are suffi-

cient to move any ordinary gate. 3. It is an easy working machine and therefore requires little repairs. The makers state that they have governors that have run for six years, with the exception of Sundays and holidays, without any repairs whatever. 4. The manner in which the friction wheels act in changing the position of the gate, gives the precise movement that is desired for what is called a differential governor without any extra device for that purpose. 5. It gives a quicker movement when opening than when closing the gate. (A recent improvement.) 6. It is not only provided with an open gate stop but has one that can be used at closed gate or part gate as may be desired. 7. It has sufficient power to handle any gate.

CHAPTER VII.

SETTING WHEELS, ETC.

Setting Wheels—Areas of Races and Flumes—Building Flumes—Position of Flumes—Decked Penstock—Details of Raised Penstock—Low Falls—Open Penstock—Wooden Flume for Turbines under High Falls—Sizes of Gripes—Draft Tube—Racks—Flood Gates.

Setting Wheels.—The wheel pit must be excavated of sufficient depth; and it should have a bottom of 2-inch plank on mud sills, unless there is rock bottom. This pit should be from 2 to 6 feet deep, extending out into the tail race its full width and depth for several feet beyond the outside flume and then gradually sloping up to the general level of the bottom of the tail race. The wheel must have ample discharge space. In case of clay or gravel formation, the flume should be stiffened by sills and posts, as it has a very heavy load and pressure to support. If it lags it will throw the wheel out of plumb. Silis must be of good, sound, durable timber, of ample size, and well framed together, and when placed must be properly level and solid. The penstock should never be smaller in the square than three times the diameter of the wheel. The larger the better, however. For wheels above forty-eight inches twice the diameter is large enough for the penstock. The penstock must be supported by proper pillars of wooden blocks or good stone, holding the sills in a permanently level position. The mud sill or under foundation must be of a most secure and permanent nature, allowing no chance whatever for any under settling or any possibility of being undermined. Heavy trimmers of good, stout timber must be neatly framed in bands across the sills to receive the floor, which must be well and tightly laid with thick plank (from $2\frac{1}{2}$ to 4 inches). The plank should be broad, say 18 to 24 inches. The floor timbers should be placed in the direction of the current, with their upper surface at the height of standing tail water, unless a draft tube is used. In large flumes each corner of the square opening left in the frame floor to receive the cylinder wheel case, should be supported by a 3 or 4 inch square post of hard, stiff timber, braced solidly on the foundation; while the bottom of the flume should be covered with 3-inch plank and the sides lined with 2-inch. In case of sand formation, in addition to making the floor perfectly tight, a tight curbing should be built up with substantial planks around and on the floor to prevent the sliding of the bank formed by the excavation. This keeps the mill foundations safe from undermining and settling. In none of these points should the work be slighted.

The hole for the wheel draft cylinder must be cut through the floor (between trimmers) of a diameter one inch larger than the cylinder measure,

to allow for adjusting wheel. Use extra care to plane off the curb of this hole until it is perfectly level, so that the wheel may set exactly level when it is in place. Be careful in adjusting the followers at top of dome, so as not to get them too tight. They must be set up by the set screws carefully, so that the shaft stands perfectly upright and easy. In setting the transmitting shaft, too much care cannot be exercised in getting it perfectly plumb; it should also rest properly in the box above. Notice that the coupling at the wheel is put together according to the marks made upon it. All of the shafting and bearings should be in perfect line.

There is many a turbine giving poor results and calling forth a spicy correspondence and wrathy visits between the maker and the buyer, when nothing but the setting should be held responsible for the low duty or unsatisfactory performance. Sometimes twin wheels will be sent out to be mounted under almost exactly the same circumstances, and one will give a good result and the other a bad, especially where there is any liability to change of head. One of the most important things to attend to is the wheel pit.

Areas of Head Race, Flume and Tail Race.—Find out how many cubic feet of water per minute are required to produce the required power. The forebay leading to the flume should be wide and deep enough to let the water pass the wheel no faster than 1½ feet per second. There should be no abrupt turns or cramped passages to cause eddies, as these reduce the working head. The tail race should have the same capacity. When possible it should have at least two feet of dead water (three or four are better) in its entire length when the wheels are not running. This allows the water which comes from the wheel to conform at once to the general level of that in the tail race (or the river). Thus no working head is lost. To obtain the required area of race in square feet, divide the number of cubic feet discharged per minute, by the wheel, by 85; that is, every 85 cubic feet of water used per minute by the wheel require one square foot of cross section in all passages to and from the wheel.

Building Flumes.—Flumes should be built properly. They are generally built too light, and by springing and bending loss of water is caused by leakage. They are generally made too small to conduct the water to the wheels without loss of head. The cross section of the flume should be not less than ten times the area of the discharge, and under high heads (say 50 feet) the area should be twenty times the area of the discharge. The spout that conducts the water from the flume or bulkhead should be not less than ten times the area of discharge. Thus, if a turbine uses 56 inches of water, the spout should have an area of 560 square inches at least. This rule is right for straight flumes. Where they make a half turn the area should be increased 50 to 100 per cent., as a square bend will often take off nearly half of the supply.

Position of Flumes.—Where turbines are used the flumes may be behind and outside of the mill, the water being carried to the wheels by openings through the foundation walls. Overshots may also be behind the mill, between it and the bank. They may have a spur gear around their outer rim on the end next the mill, and from this the main shaft may

be driven by a spur pinion; or, there may be a short shaft bearing a spur pinion on the outer end to gear with the large spur, and the inner end may bear a bevel wheel driving the upright shaft from which the spindle and stones are driven, the bolts being driven by a small shaft coupled to the top of the upright shaft and extending up through the mill. Sometimes the road and the mill yard are upon a bank and the wheel is inside of the mill. In such a case there may be a large bevel wheel made up of segments bolted upon one end of the wheel, which is made extra stout for this purpose.

Decked Penstock.—It is frequently the case in flouring mills that the flume is so placed that it is difficult to pass the wheel shaft above the

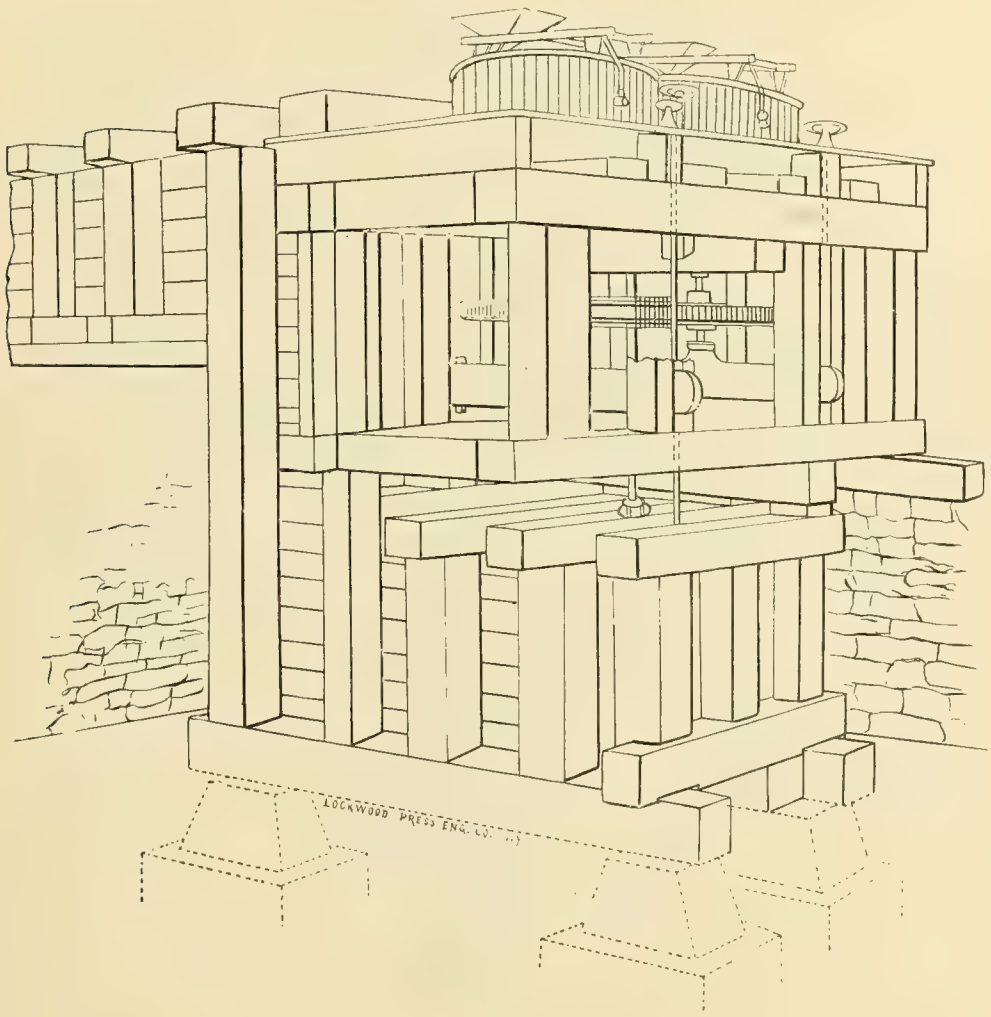


FIG. 49.—DECKED PENSTOCK.

surface of the water. This happens where the water is on a level with the second or third story of the mill and the machinery operating is on the first floor. Fig. 49 shows the method of placing the wheel in the horizontal off shoot of the flume. The upper deck of this off shoot has a stuffing box. By this arrangement the power can be brought near to the point where the work is to be done, instead of requiring a long train of gears and shafting to use up power. In building this style of flume there must be very

strong, heavy and closely fitted timbers and planks. The gate rod also passes through a stuffing box in the deck.

Details of Raised Penstock.—In Fig. 50 is shown a very strong arrangement of penstock raised upon stone piers. It will be noticed that the intermediate sills supporting the floor of the penstock are hung to the main cap by bolts. By this means the main sill does not obstruct the free discharge of water. The stone piers permit free escape of water in all directions, besides making a strong foundation.

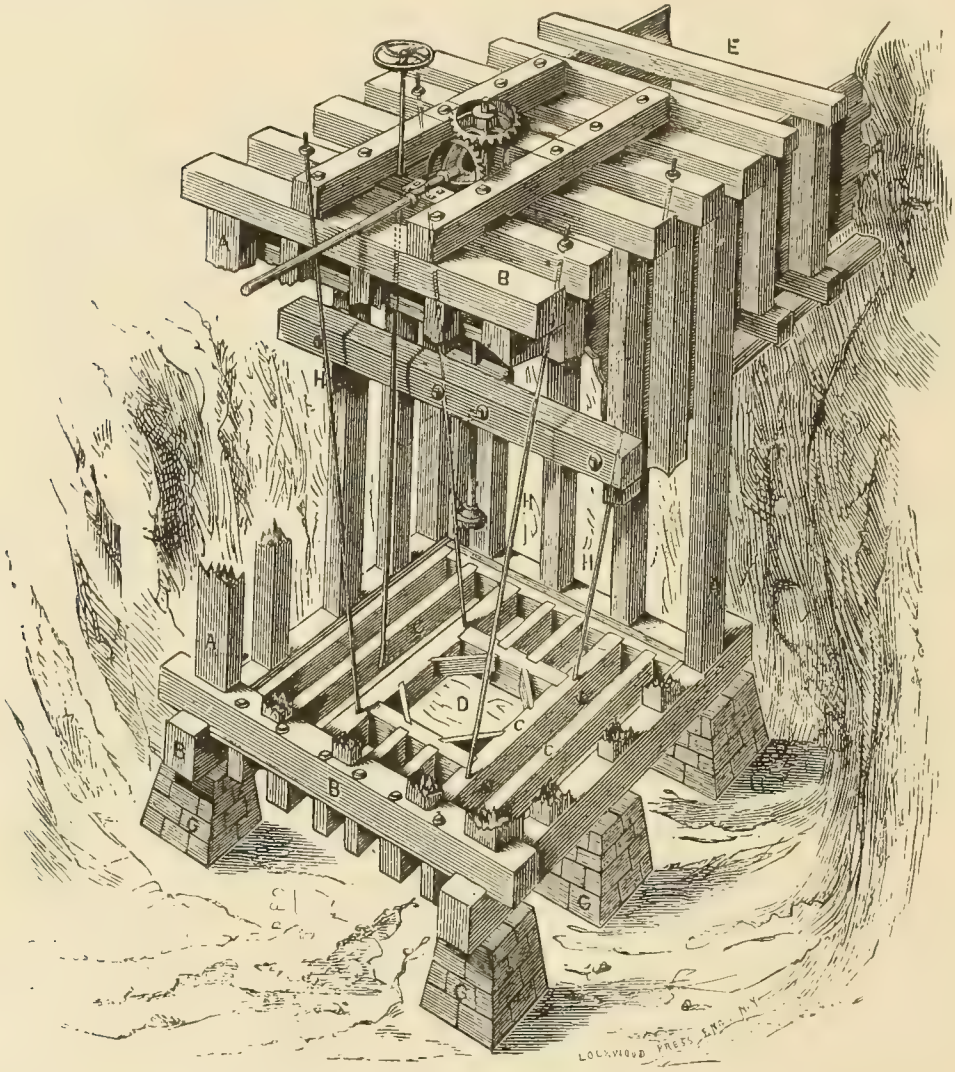


FIG. 50.—DETAILS OF RAISED PENSTOCK.

Low Falls.—In Fig. 51 is shown a good arrangement where the fall is low, the wheel being put in an open penstock and the wheel shaft driving the burr spindles direct by a large spur wheel gearing into the spindle pinions. The space below for the passage of the water should be large; and the arrangement of the stone piers should allow this. As the floor of the flume holds the weight of the wheel and of the water it should be good and strong.

The short tube from the wheel should dip at least two inches below the water in the tail race.

Wooden Flume for Turbines under High Falls.—For heads up to 75 feet, the corner posts will not need to be over 6 × 6 inches. For 40 feet head, to give enough water for a 17½-inch Victor wheel, the flume would have to be 40 inches by 40 in the clear. For the first five feet at the bottom, the plank would have to be 4 or 4½ inches thick, then above that 3-inch for

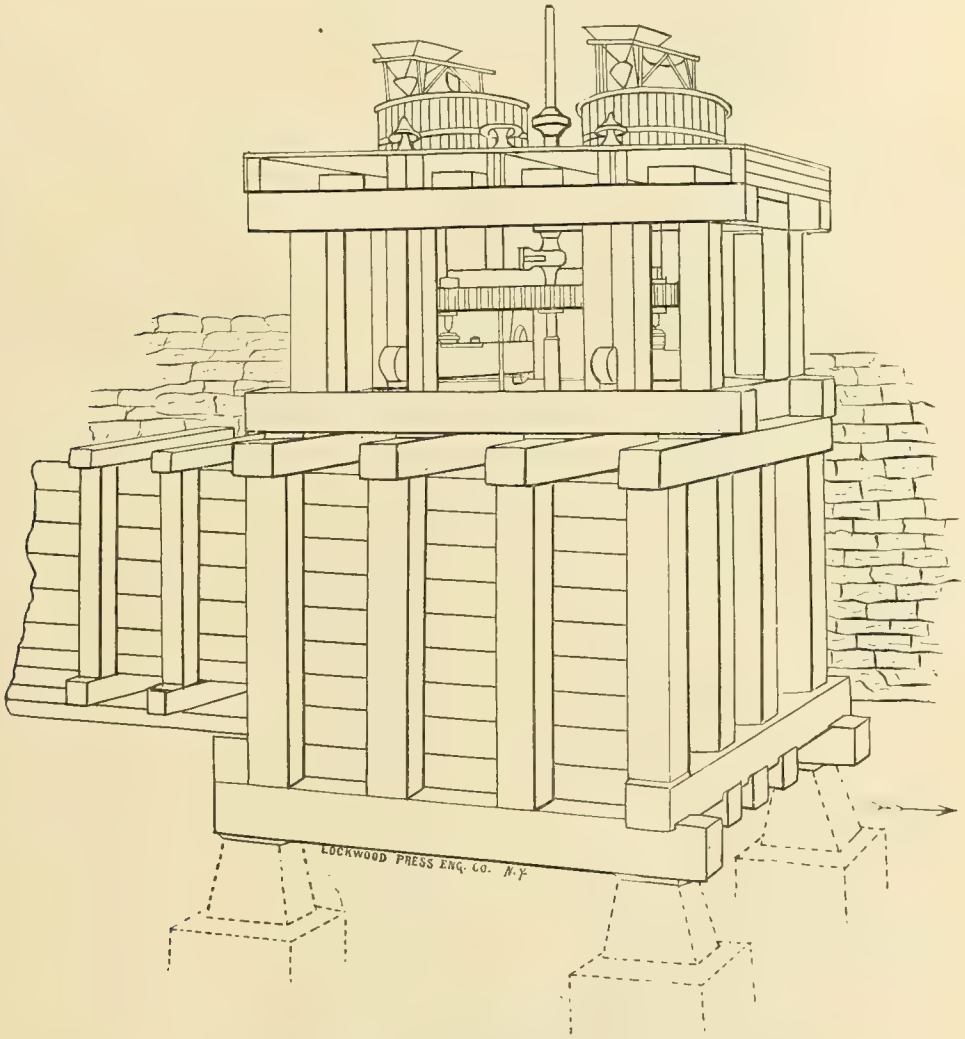


FIG. 51.—OPEN PENSTOCK.

15 feet, then 2-inch would be thick enough as the pressure got less. The horizontal flume should be 40 inches wide and 50 or 52 inches deep, allowing the water to run at nearly two feet per second. For a wheel using less water, the penstock would need to be of less diameter. All of the planks should be cut to gauge; say one-half of them 42 inches and the rest 60 for a 40-inch penstock and 4-inch planks. As a 40 × 40 inch penstock, with 40 feet of water, weighs 28,160 pounds and has a pressure of 17½ pounds per square inch, there must be a good, strong foundation, (Fig. 52).

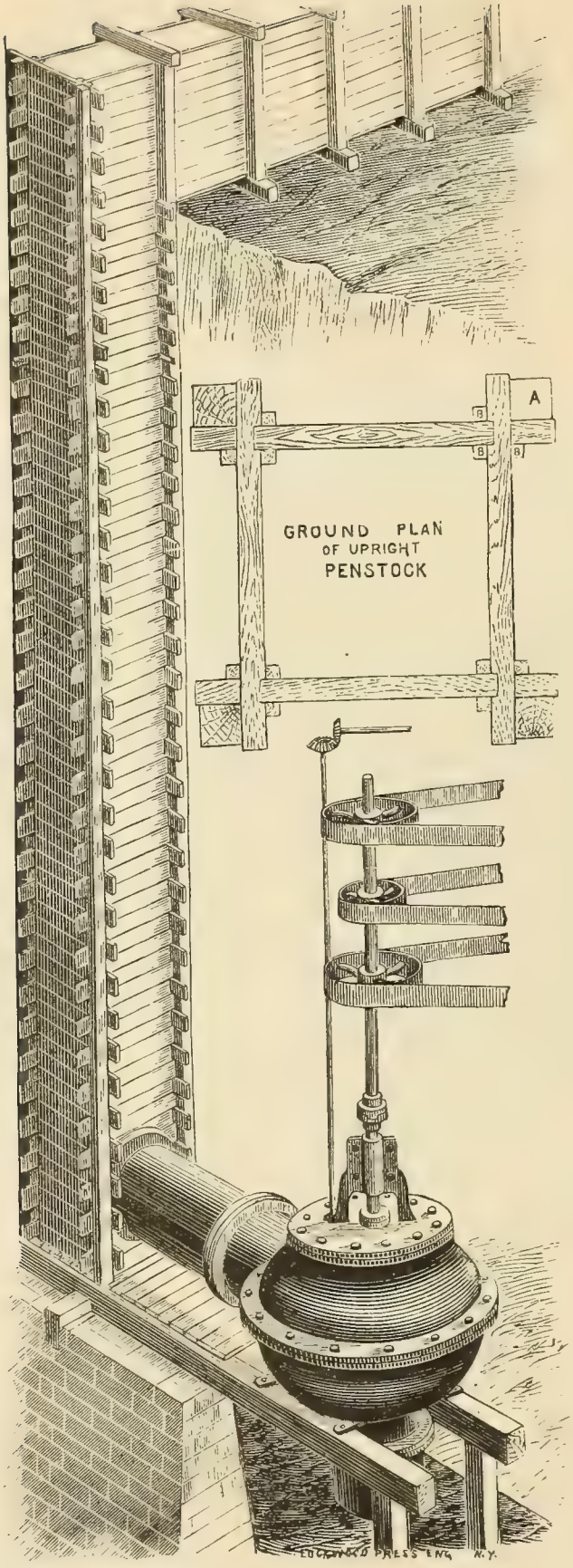


FIG. 52.—WOODEN FLUME FOR TURBINES UNDER HIGH FALLS.

TABLE SHOWING PROPER SIZES FOR WOODEN GRIPES (HARD WOOD, GOOD QUALITY), ALSO SIZES OF BOLTS AND THICKNESS OF PLANK FOR DIFFERENT SIZES OF FLUMES AND SPOUTS.

Size of Flume 6 Feet Square, made of Pine Plank 2½ Inches Thick, Gripes 2 Ft. from Centre to Centre.					Size of Flume 4 Feet Square, made of Pine Plank 2½ Inches Thick, Gripes 2 Feet from Centre to Centre.						Size of Flume 3 Feet Square, made of Pine Plank 2½ Inches Thick, Gripes 2 Feet from Centre to Centre.						Size of Flume 2 Feet Square, made of Pine Plank 2 Inches Thick, Gripes 18 Inches from Centre to Centre.					
Heads, in Feet.	Size of Gripes with Equal Sides, in Inches.	Size of Gripes with Edge or Narrow Side to the Flume, in Inches.	Size of Gripes with Edge or Narrow Side to the Flume, in Inches.	Size of Bolts, in Inches.	Heads, in Feet.	Size of Gripes with Equal Sides, in Inches.	Size of Gripes with Edge or Narrow Side to the Flume, in Inches.	Size of Gripes with Edge or Narrow Side to the Flume, in Inches.	Size of Gripes with Broad Side to the Flume.	Size of Bolts, in Inches.	Heads, in Feet.	Size of Gripes with Equal Sides, in Inches.	Size of Gripes with Edge or Narrow Side to the Flume, in Inches.	Size of Gripes with Edge or Narrow Side to the Flume, in Inches.	Size of Gripes with Broad Side to the Flume.	Size of Bolts, in Inches.	Heads, in Feet.	Size of Gripes with Equal Sides, in Inches.	Size of Gripes with Edge or Narrow Side to the Flume, in Inches.	Size of Gripes with Edge or Narrow Side to the Flume, in Inches.	Size of Gripes with Broad Side to the Flume.	Size of Bolts, in Inches.
5	5½	5 × 6	4 × 6½	1 9/16	5	4	3 × 4¼	2 × 5½	6 × 3	1 7/16	5	3¼	3 × 3½	2 × 4	8 × 2	1 7/16	5	2¼	2 × 2½	....	2¾ × 2	1 5/16
10	6½	6 × 7	5 × 7½	1 7/16	10	4 7/8	4 × 5¼	3 × 6	7 × 4	1 5/16	10	4	3 × 4½	2 × 5½	7 × 3	1 1/16	10	2 3/8	2 × 3⅛	...	5 × 2	1 1/4
15	7⅛	6 × 8	5 × 8½	1 5/16	15	5½	4 × 6 3/8	3 × 7¼	7 × 5	1 1/16	15	4½	4 × 4 5/8	3 × 5½	6 × 4	1 1/16	15	3	2 × 4	....	7½ × 2	1 1/4
20	7⅞	7 × 8½	6 × 9	1 1/16	20	6	5 × 6 5/8	3 × 8½	8 × 5¼	1	20	5	4 × 5½	3 × 6½	7½ × 4	1 3/16	20	3¼	3 × 3 3/8	....	4½ × 3	1 5/16
25	8½	8 × 9	7 × 9⅜	1 3/16	25	6½	6 × 6¾	5 × 7⅜	8 × 5⅞	1 1/16	25	5⅜	5 × 5½	4 × 6¼	9½ × 4	1	25	3¾	3 × 4⅛	....	5½ × 3	1 3/8
30	9	8 × 9¼	7 × 10⅜	1¼	30	6⅞	6 × 7⅝	5 × 8	9 × 6	1 1/16	30	5⅞	5 × 6	4 × 6⅜	7¼ × 5	1 5/16	30	4	3 × 4½	....	6⅜ × 3	1 7/16
40	..	....	....	...	40	7⅜	7 × 7⅞	6 × 8⅜	9 × 7	1¼	40	6¼	6 × 6⅜	5 × 7	9¾ × 5	1 1/16	40	4⅜	4 × 4⅜	3 × 5¼	5 × 4	1 1/16
50	..	....	....	...	50	8⅛	8 × 8¼	7 × 8⅞	10 × 7⅜	1⅜	50	6¾	6 × 7⅛	5 × 8	8½ × 6	1 3/16	50	4⅜	4 × 5	3 × 5¾	6½ × 4	1 3/16
60	..	....	....	...	60	8¾	8 × 9	7 × 9⅜	10 × 8½	1½	60	7⅛	7 × 7¼	6 × 8	10 × 6	1¼	60	5	4 × 5½	3 × 6⅜	7½ × 4	1
80	..	....	....	...	80	9½	9 × 9¾	8 × 10⅜	11 × 8¾	1⅝	80	7⅞	7 × 8⅜	6 × 9	10 × 7	1⅜	80	5½	5 × 5⅝	4 × 6⅜	6½ × 5	1 1/16
100	..	....	....	...	100	10¼	10 × 10⅜	9 × 11	12 × 9½	1 15/16	100	8½	8 × 8¾	7 × 9⅜	9½ × 8	1 11/16	100	5⅞	5 × 6⅜	4 × 7¼	8 × 5	1¼
150	..	....	....	...	150	11⅜	11 × 12⅛	10 × 12¾	14 × 10⅜	2¼	150	9⅝	9 × 10	8 × 10⅜	11¼ × 9	2¼	150	6¾	6 × 7⅛	5 × 7¾	8⅜ × 6	1⅜

Coefficient of transverse strength of a hard-wood stick 1 foot long—supported at each end, loaded in the middle—500. Use about one-fifth for safe strain. The sizes of bolts are given large; good quality of American refined iron will be found safe at double this pressure. Sticks ⅔ of the size of those in the table will hold while dry; but as they become "water soaked" they lose about one-third their strength. We often see in practice, gripes or clamps smaller than these sizes put upon flumes, which apparently hold all right until they become wet, when they gradually bend until they are removed and replaced by stronger ones. It will appear at first sight that the sizes given under 5 and 10 feet head are larger in proportion than those under 30 feet; but when we take into consideration the fact that a small stick will spring or bend more in proportion to its strength than a large one, the sizes will not be found too large for safety.

The Draft Tube.—This is used where the head is very high or the location does not admit of putting the wheel down at the tail water level. In theory it may be used up to 30 feet in height; but in practice it is best not to use over 20 feet length, because it is difficult to keep tight. It must have sufficient internal diameter to receive the cylinder of the wheel case. If of wood, it should run up through the opening in the flume floor flush with the face cants on which the wheel case rests. If of iron, it must form a tight joint with the wheel case flange. The draft tube is desirable where it is not convenient to make deep excavation. All downward and inward discharge turbines make use of the draft tube, and these downward discharge wheels have the additional advantage of being compact.

The Rack.—The flume should have a rack to prevent the passage of drift wood and other rubbish. A rack of iron bars is best; but if this is not used take wooden bars, 3 × 1 inch, set edgewise and beveled to an edge on the up-stream side. Set the bars 1 inch apart, as a maximum, and at an angle of 45 degrees. This rack should be raked out often to keep it clear. The bars should be far enough apart not to obstruct the flow of water, and should be kept clean of all trash; otherwise many inches of head may be lost. It is a good plan to put in a coarse rack several feet above the finer rack, this will retain the coarser drift. The spaces in it may be twice as large as in the fine. The entire forebay should be covered with boards from the last rack towards the wheel and over it; this is to keep the rubbish from dropping or being thrown in the water and getting in the wheel.

Flood Gates.—Sites and streams subject to freshets are of course dangerous. This is the case where the dam and the mill are in a narrow valley where there is no place for the water to back up in case of a heavy rain and spread over a great surface. In such case the dam and foundations should be made especially strong. Where there is a scarcity of water and it is necessary to keep the head high, flood gates should be used. The smaller these are the better.—A small flood gate is made by laying a strong sill at low water mark, from which the gate is swung by hinges on the down-stream side of the sill. When the gate is closed the lower edge rests upon the sill. Slight pressure from the upper side forces the gate over and outward. The hinges should be $2\frac{1}{2}$ inches below the sill top, so that the whole gate, when thrown over, will be down below the sill level. To keep the gate from being thrown over by a full pond, there is usually a lever supported by a fulcrum bolted to the side of the gate and extending up 3 or 4 inches; this fulcrum has a notch which holds the lever. The large end sticks up stream 5 or 6 feet from the fulcrum; and down stream a little over a foot. A piece of inch board, about 10 × 12, is attached on the lower side of this lever. Another piece of board, 10 × 3, is attached across the end of the lever, and to the side of the short board the lever is fastened to the gate by a piece of chain. The up-stream end of the lever has a weight sufficiently heavy to hold it down until the pressure of water flowing over the flood gate and falling upon the apron formed by the two boards on the down-stream side of the lever throws the lever over. This brings the gate down. Logs or any kind of rubbish can pass it without clogging or injuring it.

CHAPTER VIII.

MEASURING WATER POWER.

Falls—Theoretic Velocity and Discharge—Rules for Measurement by Weirs—Measurement by Floats—Stream Power—Work of Water-Wheels by Night and Day.

If water is used the millwright should know to a pound just how much he gets. Simplicity in transmission should be aimed at. There is a good deal of foolishness spoken and written on the subject of power and work and force, and the meaning of the writers and talkers is generally veiled under words to which each gives a different meaning, so that the average reader is disgusted with the whole subject, and many men neglect to study the laws of power and motion simply from the fact that they tire of the talk and nonsense. There is nothing more common sense in this world than the science of dynamics. In it a pound means sixteen ounces every time. There is nothing more exact possible than its laws. If you put a foot-pound of work into a machine there is no earthly means of getting more than a foot-pound out of it—there is no earthly means of getting even a full foot-pound of work out of it. The nearer we can come to getting a foot-pound out of it by reducing the friction, the better we shall have succeeded in utilizing it; but we cannot expect to improve upon or change the law which controls it.

Fall of Water.—A very slight declivity suffices to give a running motion to water. Three inches per mile, in a smooth, straight channel, gives a velocity of about three miles an hour. The Ganges, which gathers the waters of the Himalaya Mountains, the loftiest in the world, is, at 180 miles from its mouth, only 800 feet above the level of the sea, and to fall these 800 feet, in the long course of the water, requires more than a month.

Theoretic Velocity and Discharge.—The following table shows the theoretical spouting velocity of water in feet per second, and number of cubic feet discharged per minute, through an orifice of one inch area, under different heads, from one to forty feet, (calculated from Francis' formulas). The table represents the theoretic velocity and discharge due to an orifice conformed in all respects to the shape of the contracted vein. In ordinary practice, through orifices having parallel sides, the actual velocity and discharge will be about 64 per cent. of the table. Bearing this fact in mind, the above table may be used with reasonable accuracy in measuring the discharge of water through ordinary gate openings onto overshot and breast wheels, through waste gates, or other apertures cut in plank. Example: Suppose the opening through which the water passes onto an overshot

wheel to be 72 inches long, and the gate to be hoisted 2 inches, what amount of water will it discharge per minute, with three feet head of water in the forebay above the opening? Solution: $72'' \times 2'' = 144$ square inches $\times$ 5.78 (the discharge stated in table for an orifice of one inch area under three feet head) = 832 cubic feet, *theoretic* discharge per minute; 64 per cent. of which = 532 cubic feet, *actual* discharge per minute. There are many instances in powers already improved where the quantity of water in a stream can be ascertained, by using the above table, without resorting to measurement by weir. In ascertaining the head of water under which an orifice is discharging, measure from the surface of the water to the centre of the orifice.

TABLE SHOWING THEORETIC VELOCITY AND DISCHARGE.

Head, in Feet.	Velocity per Second, in Feet.	Cubic Feet per Minute, Area of Orifice One Inch.	Head, in Feet.	Velocity per Second, in Feet.	Cubic Feet per Minute, Area of Orifice One Inch.	Head, in Feet.	Velocity per Second, in Feet.	Cubic Feet per Minute, Area of Orifice One Inch.
1	8.02	3.34	15	31.06	12.94	28	42.43	17.68
2	11.34	4.73	16	32.08	13.36	29	43.19	17.98
3	13.89	5.78	17	33.06	13.77	30	43.93	18.30
4	16.04	6.68	18	34.02	14.18	31	44.65	18.60
5	17.93	7.47	19	34.96	14.57	32	45.37	18.90
6	19.64	8.18	20	35.87	14.94	33	46.07	19.20
7	21.22	8.84	21	36.75	15.31	34	46.76	19.48
8	22.68	9.45	22	37.62	15.66	35	47.45	19.76
9	24.06	10.02	23	38.46	16.02	36	48.12	20.05
10	25.36	10.57	24	39.29	16.36	37	48.78	20.33
11	26.60	11.08	25	40.10	16.71	38	49.44	20.60
12	27.78	11.57	26	40.89	17.04	39	50.08	20.87
13	28.91	12.05	27	41.67	17.36	40	50.72	21.13
14	30.00	12.49						

Measurement by Weirs.—Where the stream is sufficiently narrow, the simplest mode of measurement is to make a weir by taking a board long and wide enough to make a dam across the stream. Cut a notch in the upper edge of the board deep enough to pass all the water to be measured, but not longer than two-thirds of the width of the stream. Bevel the bottom and both ends of the weir, on the down-stream side, to within an eighth of an inch of the up-stream side of the board, leaving the edge or crest almost sharp, and perfectly level. Drive a stake in the bottom of the stream, a few feet back of the weir, its top exactly level with the crest of the weir. When the water has reached its greatest depth, measure with the square the depth above the top of the stake, and this measurement will indicate the true depth of the water upon the crest of the weir (Fig. 53). The amount of water the stream furnishes can now be computed from the subjoined table for weirs.

The table for weirs gives the number of cubic feet per minute that will pass over a weir one inch wide, and from one inch to eighteen and seven-eighths inches deep. The column marked "Inches depth on weir" indicates the depth of water flowing over the weir, and the second column, under 0, gives

the number of cubic feet per minute for the even inches in depth. In the third column, under one-eighth, is the amount of the second column, with the ad-

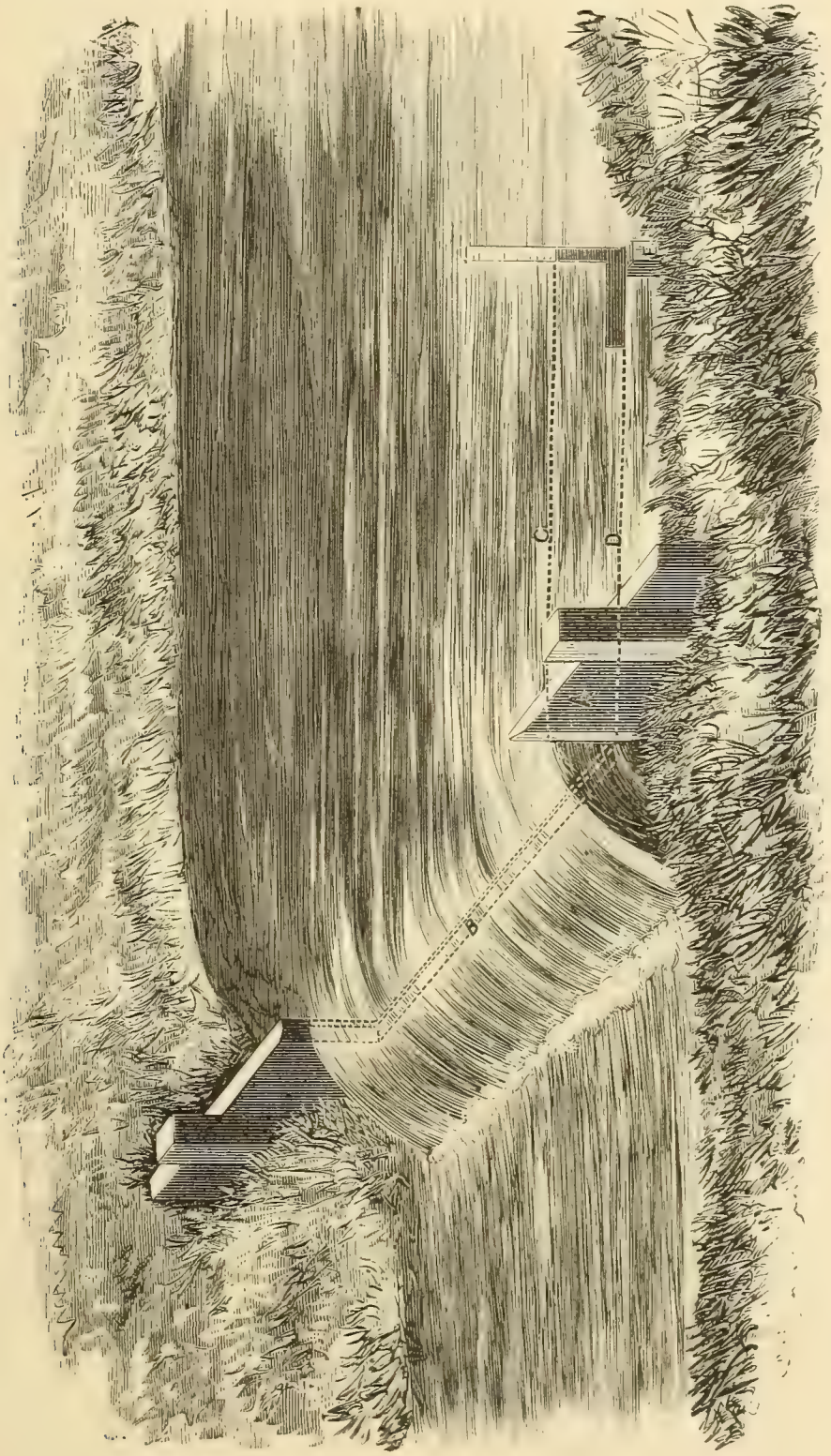


FIG. 53.—WEIR.

ditional amount due to the additional one-eighth inch in depth added, and so on across the table from left to right. By multiplying the number of cubic

feet that one inch in width will discharge, as stated in table, by the width of the weir in inches, the result will be the total discharge of weir per minute. The depth on the weir should be measured at a point just back of where the curve on the surface of the water commences.

Where the stream is too large to measure by a weir, choose some place in it where there is a moderate current or a smooth flow, and measure its velocity by a float; measure its width and average depth, and then from the hydraulic tables published in many books the flow can be measured.

TABLE FOR WEIRS.

Inches Depth on Weir.	0	1/8	1/4	3/8	1/2	5/8	3/4	7/8
1	0.40	0.41	0.56	0.65	0.74	0.83	0.97	1.03
2	1.14	1.25	1.36	1.47	1.59	1.71	1.84	1.96
3	2.09	2.12	2.36	2.60	2.64	2.78	2.93	3.06
4	3.22	3.38	3.53	3.69	3.85	4.01	4.17	4.35
5	4.51	4.68	4.85	5.02	5.20	5.38	5.56	5.74
6	5.92	6.10	6.30	6.49	6.68	6.87	7.07	7.27
7	7.46	7.67	7.87	8.07	8.28	8.49	8.70	8.91
8	9.12	9.33	9.55	9.77	9.99	10.21	10.43	10.66
9	10.88	11.11	11.34	11.57	11.80	12.04	12.27	12.51
10	12.75	13.15	13.23	13.47	13.72	13.96	14.21	14.46
11	14.71	14.96	15.21	15.46	15.72	15.98	16.24	16.49
12	16.76	17.02	17.28	17.55	17.82	18.08	18.35	18.62
13	18.89	19.17	19.44	19.72	20.00	20.27	20.56	20.83
14	21.12	21.40	21.68	21.97	22.26	22.55	22.83	23.13
15	23.42	23.71	24.01	24.30	24.60	24.90	25.19	25.50
16	25.80	26.10	26.41	26.71	27.02	27.32	27.63	27.94
17	28.26	28.57	28.88	29.19	29.51	27.83	30.14	30.46
18	30.78	31 11	31.43	31.75	32.07	32.40	32.73	33.05

Measurements by Floats.—The speed of the surface of a stream is greater than that of the stream as a body. The surface velocity is readily found by means of a piece of floating wood. From this the real velocity of the stream may be found by dividing 7.71 plus the surface velocity by 10.25 plus the surface velocity, and multiplying the quotient by the surface velocity. This may be expressed by a formula: Real velocity,

$$V = V\frac{7.71+V}{10.25+V}$$

Thus if we have a creek of thirty feet mean width, and four feet mean depth, with a surface velocity of one foot per second, we have for the real velocity of the water:

$$1 \times \frac{7.71+1}{10.25+1} = 0.774 \text{ feet.}$$

The volume of water which flows through it in a second will be $30 \times 4 \times 0.774$ = about 92.88 cubic feet, $92.88 \times 62.5 = 5{,}805$ pounds flowing every second.

If there is a fall of ten feet there will be $5{,}805 \times 10 = 58{,}050$ foot-pounds of power per second, or $58{,}050 \times 60 = 3{,}483{,}000$ minute foot-pounds; equal to

$$\frac{348300}{33000} = 105.55 \text{ H.P.}$$

The gross power of the fall is measured by the product of its height by the weight of water passing. This product is 550 foot-pounds per second per horse-power. With an efficiency of 0.7, it takes 785.7 foot-pounds per second per horse-power; that is, under these circumstances, with one foot fall, 12.6 cubic feet of water per second will give one horse-power net. With

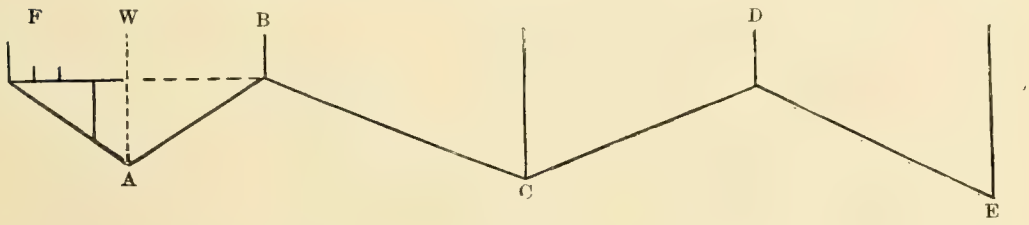


FIG. 54.

a fall of 100.8 feet, one-eighth of a cubic foot per second, or 7.5 per minute, would give one horse-power.

Stream Power.—To find the exact fall of a stream take two staves, graduated in inches and in tenths, and from four to six feet long, also a water level; then (supposing F to be the source and E the discharge) order one assistant to the source F with the staff placed perpendicular. Send another assistant to any convenient place, as A, with his staff perpendicular. Then place the water level in the centre, as at W; then order the first assistant at F to move a piece of white paper up and down on his staff until you

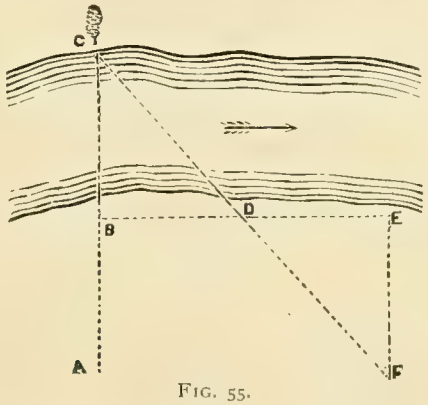


FIG. 55.

can see it through the level. Let him then know the distance of the paper from the ground, and do the same thing at the other end of the level with the other assistant at A; then send the first assistant to A, and the second to some new place, as B, replace the level and proceed as before, and so on until the second assistant arrives at E; then add all the notes of the first assistant together, and those of the second, and the difference between the two sums will be the difference in level between the two extreme stations.*

* On long runs there should be an allowance for the curvature of the earth's surface.

To measure the width of a river without actually going across it: Suppose A B be the line of survey, striking the river bank at B. Mark some tree or bush on the opposite bank, in line with A B, then lay off some convenient number of feet from B to D, at right angles to the line A B, from D to E lay off the same distance as from B to D; then walk from E, at right angles to B E, and parallel with A B, until you reach the point F, which is in line with the points C and D; then measure from E to F, which will be the same distance as from B to C, or the width of the stream.

The following is taken from the *Paper Trade Journal:*

Work of Water-Wheels by Night and Day.—An editorial paragraph appeared in a Western paper a short time ago in reference to the work of water-wheels by night and day. The assertion, too, has often been made that water-wheels do more work in the night than during the day. Of course there must be a fallacy in such an assertion. Many assert that there is an increase in the velocity by the air's becoming heavier after sunset. This is another fallacy. The subject comes up about once in every dozen years, and has as much periodical vitality as "perpetual motion." The truth of the matter can be easily demonstrated at any time by experiments. Many assert that a change in the moon produces a change in the weather, and this assertion has some foundation in truth; but how can it affect the wheel, and if the pressure of air is greater upon the water at night than in the day, it would obstruct the flow of water as much as it would tend to increase it, and even more particularly if the fall was high, because the increase of pressure near the earth would exceed the increase at a greater altitude. The advocates of the theory that water wheels run faster by night than by day have simply observed the wheels by the eye in the loosest manner possible, without measuring either the velocity of the wheel or the varying head of the water. A correspondent of the *Journal* some years ago made a test in order to settle the question. He used a very perfect apparatus for testing water-wheels, and observed their performance for several successive days and nights. He made five experiments in the middle of the day, and three in the middle of the night, on a wheel eighteen inches in diameter, running without resistance under a fall (H) of eight and more feet, running the wheel at 2,000 revolutions at each experiment, the time being calculated by noting the seconds for every 100 revolutions by a bell hammer attached to the wheel shaft. The following were the results of each experiment under the fall (H), which actuated the wheel, in revolutions per second. The revolutions are then reduced to what they would have been had the fall (H) been the same in every experiment, having one in each series, night and day, equal to 8.41′ feet. R is reduced to that H by the formula, as

$$\sqrt{H} : R = \sqrt{8.41'} : : R'$$

DAY EXPERIMENTS.

H.	*Revolutions.*	*H′.*	*R′.*
8.410 feet	4.901960	8.41 feet	4.90196
8.515 feet	4.962230	8.41 feet	4.93144
8.290 feet	4.889975	8.41 feet	4.92524
8.422 feet	4.926108	8.41 feet	4.92260
8.4216 feet	4.950544	8.41 feet	4.94713

Mean revolutions, 4.92569.

NIGHT EXPERIMENTS.

H.	*Revolutions.*	*H'.*	*R'.*
8.41 feet	4.88997	8.41 feet	4.88997
8.61 feet	4.98753	8.41 feet	4.93947
8.42 feet	4.93827	8.41 feet	4.93553

Mean revolutions, 4.92159 ; the temperature of the water being the same.

On comparing the results of the two series of experiments, it will be seen that there is a slight difference in favor of the wheel's revolutions in the day. A careful test such as this is worth all the speculation that could be entered into by theorists whose minds are prejudiced in favor of one side, and who generally come to a conclusion before they commence to investigate. The combined influence of the sun and moon is only sufficient to produce the rise in the ocean known as the tide; and even allowing for its extreme height on shores the peculiar conformation of which concentrates, so to speak, the force otherwise spread over a large surface, the total rise is hardly to be appreciated when considered with reference to the bulk of the earth. The startling fact was announced some few years ago that the discovery was made that a little less than one-third of an inch rise had been detected on Lake Erie. If only one-third of an inch of a rise takes place on so large a body of water, how much would the tide of a mill pond affect the running of a water-wheel? The theory that a water-wheel does more work by night than by day is, therefore, not in accordance with the facts.

CHAPTER IX.

BOILERS.

Combustion—Fuels—Waste of Fuel—Material for Boilers—Effects of Heating—Testing Plate—Boiler Shapes—Laterally Fired Horizontal Boilers—Internal Firing—Tubular—Water Tubes—Elephant—Proportions—Draft Area of Tubes—Steam Room—Weakening Effects of Common Steam Domes—Flues and Tubes—Grate Bars—Setting—Smoke Consumers—Chimneys—Cowls—Steam Pipe—Dry Pipe—Safety Valves—Fusible Plugs—Pressure Gauges—Glass Water Gauge—Draft Regulator—Feed Pipe—Feed Pump—Injector—Steam Traps—Blow-Off Valve—Blowers—Heating and Filtering Feed Water—Corrosion, External, Internal—Grooving—Incrustation—Character of Scale—Scale Preventatives—Management.

Combustion.—Combustion is the rapid combination of oxygen with carbon or hydrogen, and is always attended with evolution of heat. Flame is the gas or vapor which passes off during combustion, its surface burning with the emission of light, by reason of the more perfect oxidation of the carbon contained in the fuel. Hydrogen burns with a very faint blue flame. Carbon when burning should be oxidized completely into carbonic acid; if only partly oxidized it forms carbonic oxide. Only experienced persons can tell the nature of a flame by its color, or even tell its color accurately in the moment of introducing fuel. Net combustion means the pounds of fuel burned after deducting the ashes and other non-combustible material. Available heat is that part of the heat of combustion which is given up to the water in the steam boiler. By "furnace" is meant the whole apparatus for burning fuel and transferring heat to the water in the boiler, and it includes ash pan, air holes, flame chamber, flues, tubes, heating surface, and chimney. The air is made up of about seventy-nine volumes of nitrogen and about twenty-one of oxygen, together with a little watery vapor, and .0003 to .001 volumes of carbonic acid. One cubic foot of air, at 32° F., weighs .080728 pounds, or 565.1 grains; at 62° F., .076097 pounds, or 532.7 grains. One pound of air, at 32° F., takes up 12.4 cubic feet. Nitrogen neither burns nor supports combustion, but simply dilutes the oxygen in the air.

The gases of combustion are composed principally of carbonic acid, carbonic oxide, nitrogen, unconsumed air, and steam. One pound of carbon is combined with two and sixty-seven hundredths (2.67) pounds of oxygen to form three and sixty-seven hundredths (3.67) pounds of carbonic acid, and would be accompanied by eight and ninety-four hundredths (8.94) pounds of nitrogen left after the separation of the oxygen from the air. Total, twelve and sixty-one hundredths (12.61.) pounds. The specific heat of carbonic acid being .2164 and that of nitrogen .244, we have as the number of heat units absorbed in raising the gases from the combustion of one pound carbon:

Carbonic acid 3.67×2.2164,	.794	heat units.
Nitrogen, $8.94 \times .244$,	2.181	"
Total,	2.975	"

As the total heat of the combustion of one pound of carbon is 14544 heat units, we have

$$\frac{14544}{2.975} = 4889^{\circ}\ \text{F.}$$

as the highest theoretical temperature to be got by the complete combustion of one pound of carbon. This is allowing 11.61 pounds of air to one pound of carbon, which is the least possible amount of air. Allowing eighteen pounds of air instead of twelve pounds we shall have:

Carbon,	1.00 pounds.
Oxygen,	2.67 "
Nitrogen,	8.94 "
Air unconsumed,	6.39 "
Total,	19.00 "

The products will absorb heat units as follows:

Carbonic acid,	3.67 lbs.	× .2164 =	.794	Heat units.
Nitrogen,	8.94 "	× .2440 =	2.181	"
Uncombined,	6.39 "	× .2377 =	1.519	"
Totals,	19.00 "		4.494	"

The highest theoretical temperature would be

$$\frac{14544}{4.494} = 3236^{\circ}\ \text{F.},$$

or 33.81 per cent. less than when there was no excess of air admitted. If double the quantity of air be admitted, the temperature will be only 2450°.

One pound of hydrogen takes eight pounds of oxygen to burn it completely, and this requires thirty-six pounds of air to furnish it; forming nine pounds of water and setting free twenty-eight pounds of nitrogen. One pound of pure carbon takes two and two-thirds pounds of oxygen to burn it completely, taking twelve pounds of air and producing three and two-thirds pounds of carbonic acid. If this same pound of carbon be incompletely burned, that is, only to carbonic oxide, instead of completely to carbonic acid, it will consume only one and one-third pounds of oxygen, and take only six pounds of air. One pound of wood charcoal takes 11.16 pounds of air to burn it completely; good coke, 11.28 pounds; anthracite coal, 12.13; dry bituminous coal, 12.6; caking coal, 10.58 to 11.73; dry, long flaming coal, 10.32; lignite, 9.30; dry peat, 7.68; dry wood, 6. Losses in combustion take place from many causes. That of radiation from the sides of the furnace may be very largely prevented by double hollow walls. That by the use of cold air, as fed in place of hot, may be prevented in part by forcing the air through the hollow space between the double walls. There is a loss due to the escaping gases' being at a lower temperature than the surrounding air at the mouth of the chimney. This may be largely done away with by using a forced draft. The loss by unburned fuel passing through the grates and off through the chimney as smoke we shall not here consider, nor that by imperfect combustion. One advantage of heating air for furnace supply is that it acts as a corrective when too much or too little air is admitted.

Further, the affinity of carbon for heated air is greater than that for cold, and the combustion is more concentrated. There is no use in having combustion take place if the gases have gone beyond the spot where they can impart heat to the water in the boiler. There is a great saving by heating the air of combustion by means of the gases that have passed beyond the heating surface of the boiler. This saving largely results from heating the nitrogen of the air before it gets to the fire chamber, and thus preventing it from absorbing heat there. If, instead of the twelve pounds of air necessary to the combustion of one pound of coal, we let in twenty-four, there should result $3\frac{2}{3}$ pounds of carbonic acid and $21\frac{2}{3}$ pounds of nitrogen; which last would take up $21\frac{2}{3} \times .245 = 5.308$ heat units, and reduce the theoretical highest temperature to 2440°.

Different boilers burn different quantities of coal per hour per square foot of grate. The rate of combustion depends upon the coal, the grate, the flue and the draft. English coals, with chimney draft, burn about as follows per square foot per hour:

Cornish boilers, slowest rate,	4
Cornish boilers, ordinary rate,	10
Factory boilers, ordinary,	12 to 16
Marine boilers, ordinary,	15 to 24
Dry coal, quickest rate, air coming through grate only	20 to 23
Caking coal, air holes above the grate, 1-36 the grate area	24 to 27
Locomotives,	40 to 120

Ordinarily, one pound of coal evaporates from six to ten pounds of water from and at 212°, ten pounds being about seventy-one per cent. of the theoretical evaporative power of good coal or coke.

Fuels.—The various fuels used are wood, peat and coal; the latter being divided into lignite, bituminous and anthracite, and the bituminous subdivided into (1) non-caking, rich in carbon; (2) caking, and (3) non-caking, rich in oxygen. There are two general classes of wood—hard and soft; the hard including oak, hickory, beech, elm, ash and walnut; the soft being pine, birch, poplar and willow. Freshly cut wood contains about 45 per cent. of moisture; dry wood, so called, about 15 to 20 per cent. Peat is half-formed coal. There is a great deal of it in this country, especially in Indiana. The darker it is, the richer it is in carbon. It contains about 75 per cent. of water as a mininum. Lignite stands between peat and coal. It can be coked, but the coke is not good. Its heating power is low; it does not cake in the fire; it contains 10 to 20 per cent. of water. It is not much used in this country, although there is much of it in the far West. Anthracite coals are either hard or semi-anthracite (gaseous). Hard anthracite is slow to kindle and difficult to quench, and burns with an intense heat. It is smokeless and burns with a short, blue, transparent flame. It is the king of coals, but needs plenty of air. Taking up but little room, it is, where obtainable, the favorite for marine purposes. The "Buck Mountain" and Harleigh Lehigh anthracites are the finest for steaming, and are generally selected for use in competitive tests. Scranton coals are softer and less pure. Most coal in this country is bituminous. While it contains less

carbon than anthracite, it has much valuable matter rich in hydrocarbons, which give it almost equal heating power with anthracite. Bituminous coals proper are divided into caking, cherry and splint. There are also semi-bituminous, cherry and splint. There are some highly bituminous coals which are really hydrogenous or gas coals; these being divided into cannel, hydrogenous, shaly and asphaltic. Bituminous coals contain about 18 to 20 per cent. of valuable combustible material. The word "bituminous" is a misnomer, as true bitumens have no organic structure. Caking coal when heated in the furnace swells and fuses together, seems pasty and exudes gummy matter, and burns with a bright yellow or red flame with much smoke. It forms a cake over the surface of the grate. Block coal is non-caking and is very firm, so that it bears transportation; it is sometimes called free burning. Semi-bituminous coal has in part the free-burning character of the bituminous and freedom from smoke of the anthracite, besides being more readily regulated in burning than the anthracite. It kindles freely. The energy that is stored up in a pound of coal would raise 11,194,000 pounds one foot high in a minute.

One kind of wood is just as good as another when both are equally dry; of course, those woods which are dry and close are of more value by the cord than those which are porous and which contain large quantities of water. The very best kind of wood for steam and heating purposes is shellbark hickory, and the next best, white oak. These are followed by red heart hickory, red oak, beech, hard maple, Southern and Virginia pine, spruce, and New Jersey yellow and white pines. The following table gives the relative values of these woods per cord, and their weight in pounds per cord of 128 cubic feet:

Variety.	Weight in Pounds per Cord.	Relative Heating Value.	Variety.	Weight in Pounds per Cord.	Relative Heating Value.
White pine....	1,868	1.000	Beech.....	3,126	1.673
Yellow pine....	1,900	1.019	Red oak.....	3,254	1 741
New Jersey pine	2,137	1.144	Southern pine....	3,375	1.806
Spruce.....	2,325	1.244	Red heart hickory	3,705	1.875
Virginia pine...	2,680	1.434	White oak.....	3,821	2.045
Hard maple.....	2,878	1.540	Shellbark hickory	4,469	2.392

It is a mistaken idea to suppose that the temperature of the fire from one kind of fuel is really much higher than that with another fuel; if the conditions are the same there is, of course, some difference, but not nearly as much as is generally imagined.

Waste of Fuel.—Fuel is wasted in different ways. If mixed with foreign matter, that is, with slate, dirt, &c., this dead incombustible matter must be heated by the good matter, and this heat is wasted. If this incombustible matter is fusible, it melts and fills up the air spaces between the grate bars and between the lumps of coal (if coal is burned). If the fuel, whether coal or wood, is moist, heat will be wasted by being absorbed in evaporating this water. Hard anthracite is the driest. Wood contains thirty to forty per cent. of water when green, and coke, although made at

a high heat, is so porous that it absorbs water from the air, sometimes as much as twenty per cent. Fuel is wasted by not being burned at all. Sometimes this is the fault of the fireman and sometimes that of the fuel. Some coal splits and flies to small pieces; some falls apart, and these pieces fall through the grate. A careless fireman will waste fuel by too thick or too thin firing; by irregular stoking, &c. Fuel may be wasted by too much air being admitted into the furnace. This is often caused by having too large calorimeter, (cross area of the passage over the bridge wall or through the tubes). Whether admitted above or below the grate, the air should be supplied in thin, fine streams. Where the bed of fuel is not too thin upon the grate, nor unevenly distributed, there is less trouble from this cause.

But, with almost every kind of boiler setting, it is necessary to open the fire door for the purpose of slicing or feeding the fire; and this causes the entrance of large volumes of cold air, which chill the combustion chamber, doing damages in three ways—by diluting the gases of combustion, by cooling the combustion chambers by reason of their low temperature, and by causing sudden contraction of the sheets near the door. With artificial draft it is better to have smaller lumps of coal, so that the air currents will enter more irregularly, and it is better also to have a thicker bed of coal. Self-stoking devices lessen the three last named evils. So do rocking grates, which enable slicing with open doors to be dispensed with. There is much more coal wasted by falling through the grate into the ash pit than one would think. This loss is generally greatest with anthracite, being in that case nearly twenty per cent. With bituminous lumps it is less than with bituminous dust, being nearly fifteen per cent. in the latter case and only about eleven per cent. in the former.

One of the greatest causes of waste is imperfect combustion. This varies greatly with the fuel, the boiler, the grate and the stoker. Less loss arises from this with coke, hard anthracite and other fuels containing little hydrogen, than with bituminous coals. With the former it is only requisite to proportion the thickness of the bed of coals to the velocity of the draft, and to supplement the oxidizing action of the air which enters below the grates, by thin jets above the bed of coals. In the case of the soft bituminous coals, sometimes only the thickest portion of the carbon is consumed, all of the rest distilling off and passing away without being consumed. In this case either smoke or soot is formed. There are remedies for smoke which cause waste of fuel rather than saving of it. The fault of these is that they simply keep the smoke at a high temperature, from which cause the carbonic acid of complete combustion of the thickest carbon of the fuel is, by admixture with this red hot smoke, reduced to carbonic oxide. Every pound of good coal has in it about five and a half horse-powers; but in practice we think that we are doing well if we get one horse-power with two and a half pounds of coal, that is, if one pound of coal gives four-tenths horse-power, that is, four-fifty-fifths of what it ought to give.

Never slice the fires as long as the ash pit remains bright. Bituminous coal should be sliced from above; anthracite should never be disturbed on

its upper surface. If there are two furnaces they should not be fired at the same time. Anthracite coal requires less firing than bituminous. It pays to have a good fireman and engineer. In one case on record there was a fireman and engineer combined to run a seventy-five horse-power engine, at $35 per month. The coal bill was for 136 tons per month, costing $544, or about $18 per day. The next man that had the mill ran it with more machinery upon one-fourth less fuel, having an engineer at $60 and a fireman at $30.

Material for Boilers.—While the engines of to-day are generally good, most boilers are imperfect and unsatisfactory. The pressures employed are greatly increasing, having gone from 10 pounds above atmosphere to 100 and even 125 pounds as a regular thing. Boilers may be of cast iron, wrought iron, steel or copper. The latter is not much used, as it is expensive, soft and weak. Cast-iron boilers are of necessity of the "sectional" type. Their advantages over wrought-iron are that cast-iron is the better conductor, is more durable, resists corrosion better (being proof against chemical action of feed water and gases), does not blister, is less easily strained by unequal temperature, requires no braces, resists high pressures, is cheap, is easily duplicated, and mended parts are as strong as new. The objections raised are that it is treacherous at high or unequal temperatures, has hidden flaws that give no warning of weakness, is somewhat difficult to get uniform in strength, and boilers made of it prime and are deficient in circulation. The nearer spherical the parts of a cast-iron boiler are the better.

For wrought-iron boilers, the boiler plates should be strong, tough, hard, tenacious, ductile, and easily flanged and welded. Only the best iron should be used. The best is "C. H. No. 1 Flange," with a tensile strength of not less than 50,000 pounds to the square inch. Mild steel homogeneous iron or ingot iron is now growing in demand. It is homogeneous, strong, malleable, and free from laminations and blisters, but is more difficult to work than iron. When not properly made it is subject to brittleness, low ductility and cavities. Steel boilers should have drilled rather than punched holes; where they have punched ones they should be either annealed or reamed. Iron boiler plates should be subjected to a bending test—bending a two-inch strip double, cold, until the sides touch. Steel plates should be heated red, then quenched in water, and bent over double until the diameter of the inner curve is two or three times the thickness of the plate. The driving test consists in punching holes, then driving them out larger with a taper punch; the larger the holes will stretch out the better the plates. The tensile strength of iron plates should be not less than 45,000 pounds per square inch, as shown by strips of uniform cross section, free from nicks and centrally torn. The tensile strength of steel for boiler plates should not greatly exceed 60,000 pounds per square inch; above 70,000 pounds the plates are apt to be brittle; below 50,000 pounds they are likely to be spongy. No plate should be used which, after heating to a cherry red and plunging into cold water, will not allow bending over cold until the sides touch, and without breaking.

Steel boiler plates which have shown high elastic strength and ductile extension, when tested in strips before being built up into boilers, sometimes fracture in different directions. This is possible, because after being made the plate has been laid down on a flat surface to cool and having cooled more quickly at the edges than in the middle, and this puts a tensile strain upon the sheet, the outer parts being in tension first and afterwards in compression.

The only safe way to get reliable boiler iron is to buy plates bearing the private stamp of a reliable mill as well as the designation of the grade. Those who order boilers would do well to remember this fact.

Material.—About a dozen years ago Bessemer metal was offered for bridge and ship construction, which in the testing machine showed an ultimate tensile strength of from thirty to forty tons per square inch; an elastic limit from twenty to twenty-three tons, and a range of ductile extension of from 10 to 18 per cent., while the tests of plates considered suitable for the shells or barrels of boilers showed figures not much lower than these. The failures which occasionally attend the application of this steel, however, discouraged the extension of its application by engineers, who hoped that greater uniformity in the mechanical properties of the metal would gradually be obtained by the steel makers. A steel of somewhat lower tenacity and greater ductility, attended by greater uniformity in composition and behavior, was then produced, and this indicated that steel makers and engineers must look to steel of milder character for the removal of the difficulties which had attended the structural application of cheap steels, that is, steels not produced by the crucible. The result of this was that engineers specifying steel for, say, bridge work, stipulated that it should not possess more than a certain maximum tenacity—a reversal of the stipulation that had always and does obtain with respect to iron. As a further result of this, and to insure that the harder steels, of comparatively high tenacity but less certain character, should not be used in the construction of bridges, the Board of Trade regulations upon the subject limited the tensile strain on any part of a structure to seven tons per square inch. This has led to the endeavor on the part of all steel makers to produce the very mild soft steels now largely used, some of which afford the engineer no help toward producing the lighter structures which a dozen years ago it was promised that steel would give them. Boiler shells must be made nearly or quite as thick as if they were constructed of iron.

Effect of Heating on Plates.—As the temperature is raised, iron boiler plates increase in tensile strength until they have a temperature of 570° F. After this they weaken as the temperature rises. Thus, if a plate has a tensile strength of 66,500 pounds at a temperature of 570° F., it will have only 56,000 pounds per square inch from 80° down to 32°, and about the same at 720°, but at 1,050° its tensile strength will be lessened by nearly one-half, being only 32,000 pounds. At 1,240° the tensile strength is only one-third of the maximum, being 22,000 pounds; at 1,317° it is only 9,000 pounds, or only about one-seventh of the maximum. Ordinary boiler plates are 6 per cent. stronger in the direction of the fiber than across the grain.

The more the plates are piled and welded in the making the stronger they become in every direction.

Testing Plates.—To sound a boiler plate to see whether it is strong and even in quality, line it out into squares of about one foot each; strike each square separately a few blows with a light hammer, marking each square as struck, so that you will not strike the same square twice. Where the plate is good the hammer blows will sound clear and strike heavily; but if there be blisters the sound will be dull and the hammer will rebound. Both sides should be tested in this way, as sometimes a plate will test well on one side and show a defect on the other.

Boiler Shapes.—Boiler shells are either cylindrical or rectangular, or both combined. Each of these types has its advantages and disadvantages.

Rectangular shells have the advantages that they stow well away in the hold of a vessel, and in them the furnaces, tubes, flues, connections and spaces for steam and water can be better arranged than in cylindrical boilers. This is, of course, for marine boilers only. The rectangular shell is inferior to the cylindrical in strength and in simplicity of construction.

The cylindrical form does not so well adapt itself to the surroundings, the steam space is proportionally less for a given height of boiler, and there is less air and water surface from which the steam may be disengaged. The smaller the boiler the less advantageous the cylindrical form becomes; besides which, there must be more boilers for a given steam capacity, and this necessitates extra cost for attachments, connections, etc.

In some English naval vessels the boilers are partly oval or elliptical in cross section, have the larger diameter of the oval placed vertically and having cylindrical furnaces. These give larger and higher steam space for a given grate surface.

Vertical fire tube boilers with cylindrical shells have a very high rate of combustion, but low duty. This is because vertical heating surface is of less value in boilers than horizontal for two reasons: In the first place, if steam is formed on the side of a hot surface it cannot disengage itself as rapidly as from the top of a horizontal surface. In the second place, there is less contact of the heated gases with the sides of the vertical tubes than with the sides of the horizontal tubes.

By making the tubes of vertical fire tube boilers very long and by giving a very high proportion of heating surface to grate surface, their duty may be improved. This type is best adapted for road engines, launches and steam fire engines. The sphere would be the strongest shape if it were possible to employ it. It has also the advantage of not being distorted by expansion, but it would entail too much loss of space if used for shells, and it has less heating surface for its volume than any other surface that can be suggested. Boiler ends and steam drum tops are often made spherical.

Next to the sphere the cylinder is the strongest form, and it certainly is much more convenient in construction than the sphere. By its use stays and braces are not needed. Sometimes it is necessary to have flat surfaces

in boiler making, by reason of the necessity of economizing space and the proper arrangement of the interior parts of the boiler. In cylindrical boilers we find flat heads and tube sheets.

Laterally Fired Horizontal Cylinder Boilers.—The simplest type is a plain cylinder set in brick work. It is easily cleaned of scale, is very strong, easily examined and repaired, is cheap, steams well, and primes little. The plates over the fire are, however, apt to become overheated. They should be suspended in the furnace from two points in their length, each one-fourth from the end, being held by wrought-iron bolts from pieces of T iron riveted on the the upper part of the shell.

Internally Fired Boilers.—Those in use in America are generally vertical, flue or tubular, or locomotive type. The Cornish boiler is a horizontal cylinder with flat ends and one large flue passing from front to back and riveted to the two ends. In this flue is the grate. The products of combustion pass through the flue to the back ; return through brick flues along the side to near the front end, and then along the bottom to near the rear end; whence to the chimney. The course of the gases being from above downward is an advantageous one ; there are good circulation, large water surface, and hence little priming and no waste steam. The Cornish boiler evaporates about eight pounds of water per pound of coal, burning about ten pounds of coal per square foot of grate per hour as a maximum. It is well to have the internal flue corrugated, as allowing it to expand in length before the external shell is heated. The Lancashire boiler has two internal flues instead of one, thus lessening danger from collapsing. The Fairbairn boiler is a modification of the Lancashire, and is really an internally fired elephant boiler. There are three cylindrical shells—two below, containing one flue each, and one above. The Galloway boiler is a modification of the Lancashire. The two furnaces at the front end unite in one flue of an irregular oval form. In this flue are conical upright water tubes which not only support the flue but break up the flame and cause rapid water circulation and uniformity of temperature, avoiding unequal expansion and contraction. The duty of this boiler is about eight and fifty-one-hundredths (8.51) pounds of water evaporated, per hour, per pound of anthracite and nine and eighteen-hundredths (9.18) pounds, per hour, per pound of bituminous coal—each square foot of grate consuming eight and eighty-seven-hundredths (8.87) pounds of anthracite or seven and twenty-seven-hundredths (7.27) pounds of bituminous coal per hour. The "two-story" or Righter type of boiler is particularly affected in Philadelphia ; and if that city had never known it, there would be fewer widows and orphans there. It is especially subject to violent oscillation of water in the gauge.

Tubular Boilers.—In the tubular boilers the heated gases pass through tubes of comparatively small diameter, which pass through from one head to the other, under the water line, and are expanded into the heads. The type is a good one, if not exaggerated by making the tubes too long and of too small diameter. It is to be recommended where there is no liability to form scale. Too many tubes, or a proper number placed too close

together, may impede circulation, and thus lessen instead of increasing the evaporation, and may cause priming and over heating of the plates just over the grates. The combined area of the tubes may range from one-seventh to one-twelfth that of the grates—the first being for severest firing of stationary boilers with chimney draft (or for forced firing, if the consumption of coal per square foot of grate per hour be less than twenty pounds per hour), and the latter for the same boiler with fifteen pounds of coal burned per square foot of grate per hour. The slower the combustion the shorter the tubes must be. The longest tubes kept in stock by dealers are twenty feet; but even that is seldom called for, as the greatest length common in tubes under four inches diameter is sixteen feet. With tubes five to six inches in diameter they may be made twenty feet long with little fear of lessening the draft or water circulation. Three-inch or four-inch tubes are better only twelve to fourteen feet long than sixteen, although sixteen-feet tubes may be used with forced draft. But even in this last case it is better to have a damper in the chimney to increase the pressure of the gases in the tubes, and thus by retarding their flow give them more time to yield up their heat to the water in the boiler.

It is best to range the tubes in rows, so that they do not become fouled by scale as when set "staggering." Three-inch tubes are the most common size. The clear space between the outer side of the tubes should be about one-third their tube diameter, and the top of the upper row may be two-fifths of the boiler diameter from the boiler top. It may be necessary to make the top of the upper row come a very little above the two-fifths line in order to prevent the bottom of the lower tubes from coming too close to the bottom of the boiler. When there is liability to scale formation, the tubes must be a little further apart than one-third their diameter. The heads in which the tubes are expanded should be large enough to withstand the great pressure which tends to bulge them. The tendency to deform these flat sheets is greater than that operating on the convex part of the shell. In this last portion there is, if it be truly cylindrical, no tendency to deform. In fact, if it was not perfectly cylindrical in outline the outward pressure would tend to make it true. The heads should range in thickness from three-eighths of an inch in boilers thirty-six inches in diameter to five-eighths of an inch in boilers sixty inches in diameter.

For very high pressure and shells of very great diameter it is better to make them of steel than of extra thickness of iron. In counting up the heating surface of a tubular boiler add two-thirds the surface of the shell to the entire exterior surface of the tubes.

Sherwood's experiments go to show that there should be twenty-five times as much heating surface as grate surface, and eight times as much grate surface as tube area. These experiments were on marine boilers. The ordinary stationary boilers generally have the heating surface to the grate as thirty to one, and the grate to the tube area as eight to one.

A compound tubular boiler now in mind has the following dimensions:

Length of boiler,	15 feet.
Diameter of main shell,	5 "
Diameter of drum,	34 inches.
Number of 3-inch tubes,	140
Size of grate,	5 × 6 feet.
Height of chimney,	100 "
Cross area of chimney flues,	11.1 square feet.

COLLECTIVE QUANTITIES.

Water-heating to grate surface,	65 to 1.
Steam-heating to grate surface,	3.3 to 1.
Grate surface to tube area,	5.2 to 1.
Grate surface to chimney area,	8.1 to 1.

A boiler of this proportion and size supplies a double cylinder non-condensing 22 × 48 automatic cut-off engine of 325 indicated horse-powers, and furnishes steam for heating and drying.

Tests of evaporation, using Cumberland coal on a three days' run, gave the following results:

Duration,	35.5 hours.
Fuel consumed,	34,938 pounds.
Ashes,	2,365 "
Percentage of ash,	6.7 per cent.
Combustible,	32,573 pounds.
Water evaporated,	388,044 "
Boiler pressure,	81.7 "
Temperature, feed water,	205 degrees.
Temperature, escaping gases,	389 "
Fuel per hour per square foot of grate,	10.94 pounds.
Water per hour per square foot of heating surface,	1.87 "
Water per pound of fuel, under observed conditions,	11.08 "
Equivalent per pound of fuel from and at 212°,	11.55 "
Water per pound of combustible under observed conditions,	11.91 "
Equivalent per pound of combustible from and at 212°,	12.42 "

The steam is said to have been perfectly dry. Evaporation is about 11.000 pounds per hour. As the engine showed on a three hours' test consumption of 29.7 of steam per indicated horse-power per hour, the boilers must have been giving about 370 horse-powers. A common tubular boiler of the size of the main shell of this boiler would be rated at about seventy-five horse-powers, this one being rated at 125. These compound boilers thus give two-thirds more boiler power in a given floor space, and seventeen per cent. more steam for the fuel than the common cylindrical tubular boiler.

Tubular boilers are generally used. They steam well, but are not to be recommended where the feed-water forms scale, because they are difficult to clean. If there are too many tubes they are apt to prime, and the plates just over the fire are likely to overheat.

Water Tube or "Tubulous" Boilers.—In these the tubes are of small size and without rivets; hence they are strong. They are cheap to

build and to keep in order, are easy of transportation, readily conform to different places, are susceptible of enlargement, and their economy is high. But by reason of their small amount of water room they are liable to fluctuations of pressure and to scale; they are apt to prime and to overheat. Their horizontal or inclined tubes do not allow the steam to escape well; hence their steam is generally wet. The steam gathering in the water tubes renders them liable to be burnt, this danger being the greatest with the highest duty. They are liable to deposits of sediment and scale upon the tubes, and if they do not scale they are almost sure to corrode.

The French or Elephant Boiler.—This is made of several small cylinder boilers and a shell, the shell being above as a steam drum. The necks of communication should be large and frequent.

Boiler Proportions.—In proportioning boilers there are certain things to be taken into consideration which will not enable the best theoretical shape to be used. This is sometimes by reason of the best size not according with the commercial size of boiler plate. While a long grate is better than a short one to effect complete combustion, there is a certain limit, generally fixed at about seven feet, by reason of the desirability of having the boiler kept clean and the fuel evenly spread over it. If longer than seven feet it will be difficult, if not impossible, to keep the fires even on the back end.

It is not best to have the grate surface wider than forty-two inches. In order to make the surface roomier, and to facilitate firing at the back, the grate slopes down from the front to the back about one inch to the foot. If the ash pit is too small, the air will rush through it too fast to supply the combustion on the grate. The incoming air should have as low a velocity as possible. The height of the surface above the grate must be sufficient to let the gases of combustion mingle properly. The higher the rate of combustion, the higher the furnace should be. In marine boilers twenty-four inches of height is enough, while in locomotive forty-eight is common. Bituminous coal needs a larger combustion chamber than anthracite. The gross area of space over the bridge wall should be as small as possible, to give the gases a high rate of speed in passing this point. By this means they are allowed to mingle more freely. The higher the rate of combustion, the larger in proportion this cross area should be. The more rapid the draft the larger this cross area must be. It is best that the bridge wall opening should extend all of the way across the furnace, and that the cross area should be regulated by the height.

The back smoke connection should be large in order to give the gases of combustion time and opportunity to complete their combinations before entering the tubes. There should also be room enough to admit a man for the purpose of making examinations, repairs, &c. Water spaces should be as wide as possible, and never less than four inches in the clear. There must be room enough between the furnace and the tubes to let a man in to scale the crown sheet of the furnace and to make repairs. For this purpose also there should be man-holes not smaller than 13 × 11 inches, and better, 15 × 12, oval in shape. The larger the water level the less trouble will there be with foam-

ing and priming. If the steam space is too small there will be trouble from the water lifting into the steam pipe when the engine makes sudden demands upon the boiler.

Wherever boilers are intended to carry high pressure steam, the furnaces must be cylindrical, and they must be perfectly cylindrical, being made with butt joints and not with laps. The strap should be inside of the flue, on one side, and below the grate. If so placed, it will be accessible for calking, will not be in contact with the fire, nor in the way of hauling the ashes. The lengthwise seams would be better if welded instead of riveted. Long flues should be stiffened by flanges or by encircling bands at suitable lengths. In the Adamson joint, two outward flanges of the flues come together with a five-eighths inch wrought-iron ring between them, the sections being connected by single riveting. By this method the fire does not touch any laps or rivets, and the joint may be calked both from the inside and the outside. Sometimes the different lengths of the furnace flues are connected and stiffened by T iron rings. When this is done, there should be an interspace left between the two ends of the flues. This allows the joint to be calked from the inside as well as from the outside, and there is also less liability to overheating at the seam. With such a joint as this, the two flue lengths must have exactly the same diameter, or the joint will give trouble.

In long boilers there is often serious trouble by grooving, owing to the contraction and expansion of the furnace flue. To lessen this trouble, the "bowling hoop" is used. The disadvantage of the bowling hoop is that there is a double thickness of plate, and the rivet heads are in the fire at each joint. An angle iron hoop is preferred by many to one of T iron. It is best made in halves, so that it may be passed in at the man-hole, and then riveted to the tubes in position. This obviates the removal of the tubes or cutting any holes in the boiler. It is best not to let the angle iron touch the tube, but to make the interior of the hoop two inches greater than the outside diameter of the flue, placing rivets six inches apart and letting each rivet run through a blocking piece about an inch long. The angle iron hoop has the advantage over the T hoop that its single flange hinders the escape of steam less and gives less room for deposit.

All smoke connections must be so designed and made as to give the gases large and free passage. As it is necessary to get at the tubes for sweeping, replacing or calking, the smoke connections are often provided with large hinge doors. Sudden enlargements should be avoided; there should be no sudden bends; the current of gases coming from one set of flues should never cross other currents entering the same passage, and they should be partitioned apart until they both have the same direction.

With high pressure cylinder boilers it is preferable to make the boiler proper complete in itself, making the front connections and uptake separate structures. It is necessary to line the uptake and connection with fire bricks. The uptake must be strong enough to carry its own weight and that of the smoke pipe.

Draft Area of Boiler Tubes.—The appended table gives the draft area and heating surface of boiler tubes and flues, which have been computed on the basis of the thickness of such tubes taken from the price lists of American manufacturers. This table will be useful to designers and users of steam boilers, and save time in calculation in ordinary practice:

External Diameter in Inches.	Draft Area in Square Inches.	Draft Area in Square Feet.	Heating Surface per Foot in Length, in Square Feet.	Number of Tubes or Flues=1 Square Foot of Draft Area.
1	.575	.0040	.2658	250.0
1¼	.968	.0067	.3272	149.3
1½	1.389	.00964	.3927	103.7
1¾	1.911	.0133	.4581	75.2
2	2.573	.0179	.5236	55.9
2¼	3.333	.0231	.5891	43.3
2½	4.083	.0284	.6545	35.2
2¾	5.027	.0349	.7200	28.7
3	6.070	.0422	.7854	23.7
3¼	7.116	.0494	.8508	20.2
3½	8.347	.0580	.9163	17.2
3¾	9.676	.0672	.9818	14.9
4	10.93	.0759	1.0472	13.2
4½	14.05	.0976	1.1781	10.2
5	17.35	.1205	1.3090	8.3
6	25.25	.1753	1.5708	5.7
7	34.94	2426	1.8326	4.1
8	46.20	.3208	2.0944	3.1
9	58.63	.4072	2.3562	2.5
10	72.23	.5016	2.6180	2.0

In a flue return tubular boiler the area of flues should be about 20 per cent. and the draft area of uptake about 25 per cent. greater than the draft area of tubes. Good conditions for combustion and steaming are realized when the grate surface is 8 times and the heating surface about 200 to 240 times the draft area of tubes.

In the construction of steam boilers there are many other things to be done besides putting plenty of grate and fire surface. The fire surface must be properly disposed and located, and the circulation of the water must be good, so that the plates will not be burned on the fire side. The boiler should be as hot in one place as in another, to prevent injury from expansion. It should be readily accessible for cleaning and repairs. The water spaces should be ample. The stop valves must be readily got at, and such as to be opened or closed quickly and tightly. The velocity of steam in the pipes should not be more than 100 feet per second.

Steam Room.—A certain amount of steam room is necessary in order to prevent the lifting of the water in the boiler, when sudden demands are made upon it by high piston speed; but too much steam room makes the boiler too large and too heavy, and increases the cooling surface. The higher the rate of expansion and the fewer revolutions per minute of the engine, the more steam room is required. Marine boilers generally have about eight cubic feet of volume for each cubic foot of water evaporated per hour. Of this volume about one and five-tenths cubic feet are in the steam

room, and six and five-tenths in the water room, furnaces and tubes. The steam room should, under the most favorable circumstances, contain at least enough steam to last the cylinders fourteen seconds; and it would be well to have enough to last the cylinders twenty seconds. A high and narrow steam room is better than the same volume with greater lateral dimensions. For this reason steam drums are of more use simply as steam room than steam space in the shell below them ; for this reason, also, steam chimneys, that is, annular steam spaces surrounding the base of the chimney, are very efficient, because they not only superheat by reason of the increased heating surface, but, by affording great height of steam room, permit the water that is carried up mechanically to be deposited and not carried over.

Weakening Effect of Common Steam Domes.—W. Barnet Le Van, a prominent engineer of Philadelphia, who has given much attention to the causes of steam boiler explosions, gives his views at length in a paper which we herewith reproduce, on the weakening effects of domes as

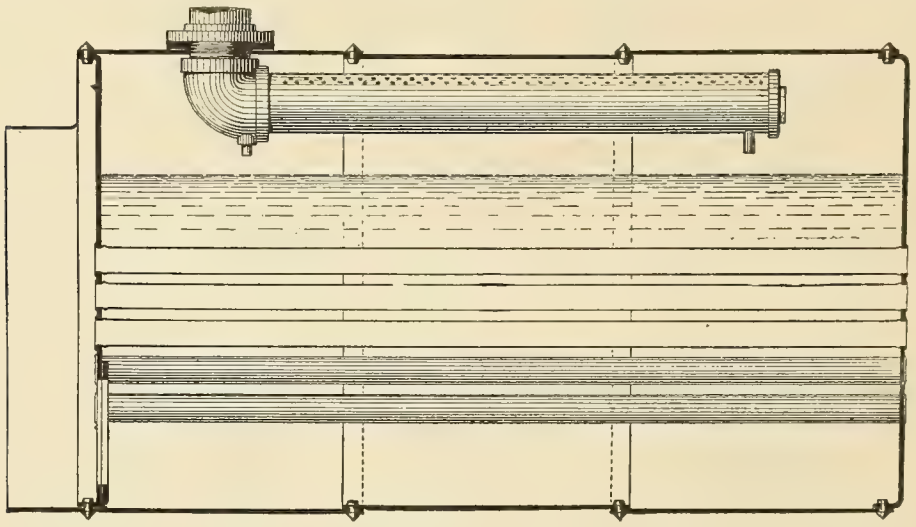


FIG. 56.

usually applied; his positions and deductions are wholly tenable, and we agree with them practically and theoretically. He says: "The weakening effect of cutting large holes in boiler shells for receiving steam domes, or drums, is well known among boiler makers, and in order to preserve as much as possible of the original strength of the shell they cut a hole much smaller than the diameter of the steam dome, with the idea that the shell is weakened only in proportion to the size of the hole cut, which is a great error. The weakening effect is proportioned to the section of the dome adjoining the shell, independent of the size of the hole cut. The effect of an equal pressure upon both sides of that part of the shell covered by the dome is to deprive it of its direct acting tensile strength, in resisting an enlargement of the circle of the boiler, and to substitute in its stead that resistance made by a curved plate pulled in the direction of its chord. As this is but an inconsiderable fraction of tensile strength, the boiler is weakened in proportion. To make this good the boiler should be stayed

to compensate for the section of plate represented by the diameter of the dome. But better still is to have *no dome at all.* If domes are used at all, great attention must be given to the construction of them. They should be contracted at the lower part, and connected to the shell of the boiler by a neck of moderate diameter, and of such strength as to thoroughly make up for the cutting away of the shell of the boiler. A simple calculation will show that, by increasing the dimensions of a 48-inch diameter boiler, 12 feet long, to 51 inches diameter, as much additional capacity will be obtained as is contained in two steam domes of the ordinary size (30 × 24), and the larger-sized boiler, without the steam dome, will resist more steam pressure per square inch than the smaller boiler with the steam dome attached. By slightly increasing the diameter of the boiler it is scarcely weakened, and the extra iron required will be but one-fifth that used in making the steam

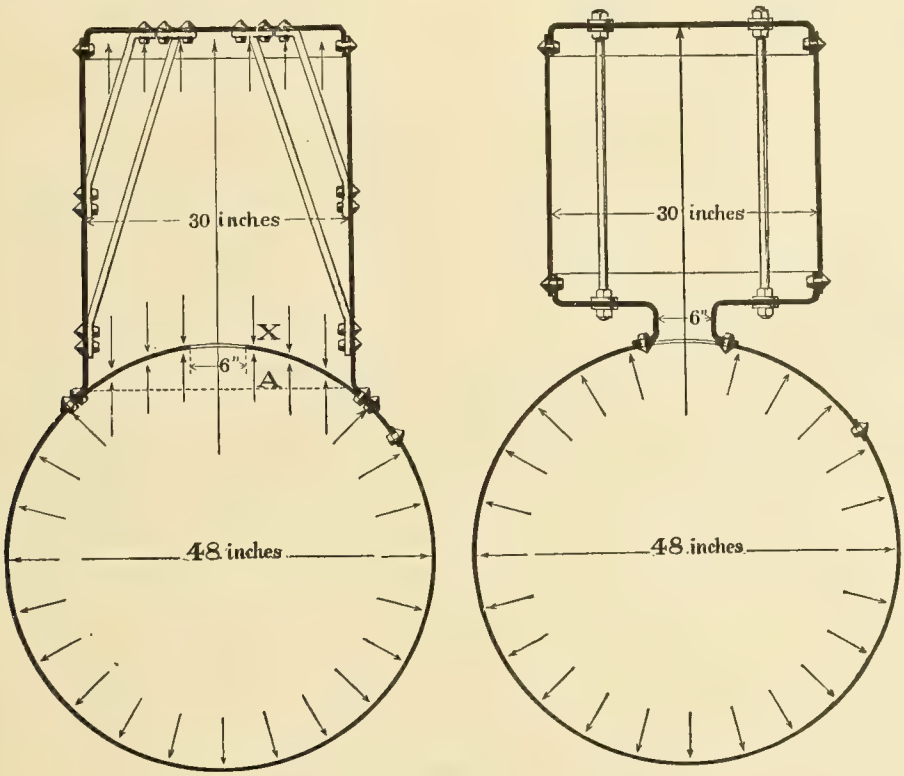


FIG. 57.

dome, saying nothing of workmanship. A substitute for a dome is a pipe placed inside of the boiler near the top of the steam space, the upper part of the pipe being perforated with small holes. The smallest holes should be made where the ebullition is the greatest, which is over the fire-grate. It would require 250 holes of $\frac{1}{4}$ inch diameter, or 1,000 holes of $\frac{1}{8}$ inch diameter, to give the area of a circular opening of 4 inches diameter. (Fig. 56.) It is not generally known, but nevertheless is a fact, that a large number of boilers sent out are under internal strains, resulting from bad workmanship, which, no doubt, in some cases will equal the proposed working pressure. These strains reduce the ultimate strength of the boilers

independent of their being further weakened by cutting large holes for domes or necks.

"The pressure in a cylinder boiler practically radiates from the axis of the cylinder to the circumference, tending to preserve the circular form, and thus keep the plates of the shell in equal tension. Now, when a steam dome is used with a small hole cut in the shell this effect is destroyed, from the fact that, the instant the pressure inside and outside that portion of the shell plate covered by the dome are equal, it becomes merely a bent stay and affords but little strength to resist the bursting pressure on the shell of the boiler, having a tendency to become straight, as shown by the dotted lines at A (Fig. 57), and having no support from internal pressure to assist it in keeping a cylindrical shape, the pressure under and over the shell being the same as shown in the cut at X, causing the shell of the steam dome to be thoroughly strained and brought to a bearing, thereby stretching the boiler shell plates to the extent of their greatest elastic limit, and reducing its strength to a minimum."

Boiler Flues and Tubes.—One method of fastening the tubes into the tube sheets is to expand them by means of special tools, which not only give the metal perfect contact with the sides of the holes in the tube sheets, but in some cases form shoulders either inside or outside, or both. Another method is to drive in a ferrule, which may be riveted over the end of the tube. Ferrules, while they make a tight point, obstruct the draft, and not only prevent the cleaning of the tubes, but give lodgment for soot and ashes. Tube ends should be annealed before being expanded. If the point is properly made the tube is not only perfectly tight, but acts as a stay or brace between the two sheets; but the tube plates must have some play to allow them to give when the tubes expand, or else the tubes must have a chance to bend sidewise, which will be the case if they are very long. The tube plates should be good and thick, so as to give enough bearing to make a good point and to be stiff. The holes must be just the diameter of the tubes, so that the tubes need not be expanded excessively, which is apt to split them. It is better to counter-bore at the outer side, and to take off the burr on the edge of the sheet. The tube is cut about one-half inch longer than the extreme outer distance between the sheet faces, one-fourth inch being left at each end to project; this one-fourth inch is expanded, sometimes slightly turned over. Boring the tube holes slightly conical with the large diameter outside gives the tube greater holding power. In some boilers the sheet is made very thick and, instead of being bored conical, there is a shoulder or counter sink from the outer side, allowing the tube ends to be turned over in the ledge. This arrangement saves the tube ends from wear by the action of solid articles which are borne through them at so rapid a rate. The ends of small tubes may be riveted over, after expanding, by a "boot-leg" tool or, if the tube is large, by means of a round-faced copper hammer. Steady rolling the tube ends over with the expanding tool is much better than with the quick blows of the hammer. There is such a thing as too much expansion of tube ends; they may be made too thin by this process. If the pressure will be from

within, forcing the heads out, it is better to expand the tubes on the outside ends; but if the pressure tends to push the tube sheets together, the shoulder should be on the inside. In taking out expanded tubes, iron ones are generally rendered of no value, and brass ones must have new ends and brazed on. Copper will not do for tubes of locomotive boilers, because the friction of the cinders, caused by the artificial draft, wears it out. It will not do for marine boilers, because of the galvanic action between copper and iron in the presence of salt water. There is some trouble also in using copper tubes with iron boilers, by reason of the different expansion of copper and iron by heat. Brass tubes have all of the advantages of copper, and none of their disadvantages. They are ductile, have greater conductivity than iron, expand less under heat than copper, do not corrode, and do not produce much galvanic action. They are more expensive in first cost than iron tubes, but are more injured by burning than iron. Brass tubes are less injured by expanding them in the tube sheets than iron.

Corrosion will render the tubes unsafe sooner than the plates, because the tubes are thinner than the plates, and though, because of their smaller diameter and the pressure being on the outside, the tubes will bear just as much pressure as the shell, when both are of their ordinary thickness, a diminution of one-sixteenth of an inch in thickness might not render the plates unsafe, while the tubes would be so.

Whitehead, an English engineer, has invented seamless boilers, each made from a single ring of cast steel, rolled to the proper dimensions for the cylindrical shell, the heads being put on with bolts. There is no doubt that such a boiler must be stronger than one with lengthwise seams.

Grate Bars.—It is important that the grate of a boiler shall have proper dimensions, construction and position, in order to give regular and thorough combustion of fuel, high duty, regular steaming, and prolong the life of the boiler, while lasting well itself and giving little trouble to the fireman in handling various classes of fuel—of course, within a certain range. As regards the quantity of grate surface, Watts' rule was one square foot per horse-power, or per cubic foot of water evaporated per hour. But the grate required depends on the kind of water and fuel, the details of boiler and setting, and whether the draft be natural or forced. Watts' allowance may be reduced to three-fourths of a square foot for good, and one-half square foot for best coal. The square feet requisite for the various types of boilers may be found by dividing the number of pounds of water to be evaporated per hour (from and at 212°) by the following numbers:

Cylinder	75	Vertical tubular	79
Flue	77	Locomotive and portable	80
Horizontal tubular	78		

Stationary boilers will burn, per hour, per square foot of grate, almost as follows:

	Natural Draft.	Forced Draft.
Bituminous	10 to 25 lbs.	20 to 50 lbs.
Semi-anthracite	10 to 20 lbs.	20 to 40 lbs.
Hard anthracite	8 to 16 lbs.	16 to 32 lbs.

Forced drafts necessitate thicker fires and greater care in firing than natural. The area per pound of coal for different types of boilers and different drafts is about as follows:

For externally fired boilers,	with moderate draft.....	.08	sq. ft.	per lb.	of coal.
" "	with quick draft.....	.06	"	"	"
" "	with forced draft.....	.04	"	"	"
For internally fired boilers,	with quick draft.....	.03	"	"	"
" "	with forced draft.....	.02	"	"	"
For locomotive boilers		.01	"	"	"

It is best to make the grate surface somewhat excessive, so as to allow for poor coal and slow draft, and to reduce it sufficiently by brick work along each side wall. The annexed table, from Barr, shows the width and length of grates and the area in square feet, as usually supplied tubular and flue boilers; also the amount of coal required per hour when burned at the rate of 12, 14, 16, 18, 20 pounds per square foot of grate per hour.

Grate.				Coal Required per Hour.				
Diameter of Boiler. Inches.	Width. Inches.	Length. Inches.	Area. Sq. Feet.	12 Lbs. Pounds.	14 Lbs. Pounds.	16 Lbs. Pounds.	18 Lbs. Pounds.	20 Lbs. Pounds.
36	45	48	16.0	180	210	240	270	300
38	47	48	15.7	188	220	251	283	314
40	49	48	16.3	196	228	261	293	326
42	51	52	18.4	221	258	294	331	368
44	53	52	19.1	229	267	306	344	382
46	55	52	19.9	239	279	318	358	398
48	57	52	20.6	247	288	329	371	412
50	59	60	24.6	295	344	394	443	492
52	61	60	25.4	305	356	406	457	508
54	63	60	26.3	316	368	421	473	526
56	65	72	32.5	390	455	520	585	650
58	67	72	33.5	402	469	536	603	670
60	69	72	34.5	414	483	552	621	690

In vertical tubular boilers there is not the same room for variation in grate area to suit the fuel as in horizontal; but the fuel must be chosen to suit the grate. Anthracite nut coal or crushed coke is generally best. Bituminous needs slow burning and stoking in small pieces. To facilitate firing, the grate is usually set somewhat lower at the rear end. The mean distance with external firing should be about 30 inches when bituminous coal is used, 20 to 24 for semi-bituminous, and 18 for hard anthracite. The bars should get their strength from depth rather than width; and the problem in making them is to get as much air space as possible without letting the fuel through, and at the same time to render as light as possible the arduous labor of slicing.

For burning saw dust, excellent results are obtained by using grate bars, made for ordinary furnaces, of flat plates of a width of about six inches, and running lengthwise of the furnace. Each of these plates has two ribs of a depth of about four inches by one-half inch thick, for supporting and preventing the plates from warping. The plates are perforated by holes

three-eighths to seven-sixteenths of an inch in diameter, which are largest at the bottom to facilitate molding and prevent the holes from stopping up. (This style of grate has also been used for years upon locomotives for burning soft coal, and is adapted to burning coal dust, coke, and other miscellaneous fuels.)

Coal is burned upon grates composed of alternate bars and spaces. In some cases there is a dead plate about twenty inches long without any perforations. This is at the front part of the grate, and is used with bituminous coal. Upon this grate the coal is thrown and partly volatilized by the glowing mass in front of it, the resulting coke being pushed forward when new coal is added. Overheating of grate bars is prevented, or partly prevented by the currents of air passing up beeween the bars, and also by a thin layer of ashes. The advantage of large air spaces is not only that they furnish a large air supply to support combustion, but they keep the grate bars cool. If bars are of a bad shape, or if the spaces are choked, or if the fire is too hot, the bars will bend vertically or warp sideways, and partly melt on top. Grate bars are destroyed more rapidly by "brassy" coals (those containing sulphur), or by those forming easily fused clinker, because the clinker chokes up the air passages and the sulphur rapidly eats into the hot iron. The top of a grate should be accurately plane; if any bar projects above the level of the others, it is apt to be burned and to be displaced in stoking. Hollow grate bars, through which a current of cold air or water passes, have been proposed and used; but they are expensive and difficult to keep in order; hence have not found their way into public favor and extended use. Wrought iron grate bars bend and warp more easily than cast iron, but they can be straightened again, which is not the case with cast iron. They are not so easily broken, melted nor fused as cast iron. They may be made thinner than cast-iron bars; hence will give more air space per square foot of grate surface, and are somewhat lighter than the cast iron. The easiest way of making them is to rivet two plain bars together with thimbles between them for distance pieces at the ends and in the middle, the heads of the rivets being half as high as the desired space between the bars, so that if all the rivets are in line the bars will be of an even distance apart. Short bars are easier handled than long ones, and are less apt to warp or twist by overheating. Grate bars should be thicker at the top than at the bottom to facilitate the inflow of air, the fall of ashes and the slicing of the fire from below. If the bars are over thirty inches long, they should have projections at the middle of their sides to stiffen them. They are generally made in pairs so as to give less trouble in handling, and the single bars are provided in order just to fill the grate width if an odd number of bars is needed. In order to prevent clinkers from sticking to the bars and filling the air spaces, it is well to have a shallow groove in the top edge of the bar. This will not only prevent the clinkers from sticking, by reason of the ashes it will contain, but will, for the same reason, slightly prevent melting or burning of the top of the bar. There should be allowed at the end of the bar a space not less than the width of the air space, in order to allow for the expansion of the bar.

Boiler Setting.—Not only the economy of fuel consumption and the regularity of steam generation, but the life and safety of the boiler very largely depend on the mode of setting. As a rule, boilers are bought of makers more or less conversant with proper proportions in construction, and set by other parties than their builders—by parties who are not informed concerning the proper relations of grate and heating surface to length, cross section and position of flue passages, and who are not interested in producing from the boilers they are given to set any special amount of steam per pound of coal or per square foot of grate or heating surface. It is perhaps within the bounds of accuracy to say that four out of five boilers are badly set. The mode of setting boilers should be determined principally by the nature of the boiler and of the fuel; and the style of boiler should be carefully decided upon by the nature of the service desired. It must be remembered that perfect combustion is the first and principal desideratum. Without this no good results can be obtained or expected; with it many minor disadvantages are in part counteracted.

Horizontal, Externally Fired Cylinder Boilers.—A very common and cheap mode of setting horizontal, externally fired cylinder boilers employs straight walls only at the end, the back end having a horizontal cast-iron plate or bracket riveted to it, by which it is upheld by the rear wall of the brick setting. This plate arrangement is better than arching over the rear end, as in the case of tubular boilers the rear ends of the tubes are quickly and readily accessible and seen under good lights for examination or repairs. Still the arch offers the best passage for the gases of combustion. Bricks are better than stone for foundations. Brick walls are much better hollow (that is, of two single thicknesses with an air space between them) than solid. The walls are carried up straight to the level of the top of the shell, and filled in with some good non-conducting material, either solid or filled with air spaces, the latter being far preferable. A mixture of sawdust, coal ashes (not wood) and plaster of Paris, makes a good insulator. It should not touch the iron boiler shell, but be separated from it by a wooden lagging, made by kerfing out strips an inch thick, four inches wide, and long enough to reach over and around the upper semi-circumference of the shell, and building up the arch (by narrow board strips) laid on these arches, which latter are about three or four feet apart, and hold the boards off from the shell and leave an air space. It would, perhaps, be about as well to cut these longitudinal strips into lengths equal to the distance between centres of the arched bearers, so that sections of three or four feet in length of the board lagging may be removed at will. Every precaution which facilitates ready examination is valuable and desirable. To carry out this idea more completely, the writer has devised a mode of making the non-conducting covering or plaster, in readily removable sections. This is to lay on top of the board lagging, before "grouting" with the plaster, some lengths of wire which hug the lagging closely, their ends coming up at the sides, so that when the plaster begins to set, these wires may be used to cut it into blocks, any one of which may be removed without disturbing the others. All the lengthwise wires may be laid down first, and

then all the cross wires; they being removed in the reverse order. Sand should never be used, either wholly or in part, for this filling. It is best to cover the top of it with a stout canvas, which will prevent the percolation of water through the joints and consequent rusting of the outer surface of the plates. Where a brick arch is used, it should not be allowed to touch the boiler shell, especially if the joints be made with lime mortar. But the use of lime mortar in boiler setting cannot be too strongly condemned. In the furnace proper, fire clay should be used to make the joints of the fire brick there necessary. Some shells are upheld by cast-iron lugs riveted to the shell at its medium line. They should correspond accurately to the curve of the shell, and be of suitable braced shape in order that they may not crack or give way. In a 12-foot boiler four are necessary, two on each side, they should be placed three feet from each end. Sometimes, to allow for expansion and contraction in length, the rear end is left to be supported on rollers, instead of being hung by the lugs. The same object would be attained by setting a plate in the brick work under each rear lug and putting a roller between it and the lug. The plate should extend a little further back than the lug, and there should be a brick abutment at each end to keep the roller in place. A crop end of $2\frac{1}{2}$-inch shafting would make an excellent roller. It must be remembered that the expansion and contraction of a boiler, unless allowed for (no earthly arrangement will prevent it), will surely break up and destroy any setting. When a mud-drum is used (and it is generally desirable to have one, say one-third the diameter of the boiler shell, and fitted with a man-hole as well as with blow-offs), it may extend either across the under side of the boiler, forming a support for the rear end, or it may run lengthwise and its head project through the rear wall. The walls heretofore referred to are for supporting the shell. There are others built across to form furnace and ash pit. The first from the front end is the bridge wall, which is peculiarly subject to destruction by the fierce heat playing around it. It should be of special thickness (preferably hollow), and faced with fire bricks. The fire-brick furnace walls should be brought up to the water line. The grates have a rest of about an inch in the bridge wall plate, and on a bearing bar fastened in the fire brick. They are generally slightly the lowest at the rear end, to facilitate stoking. As regards distance from the under side of the boiler, it should be regulated strictly by the kind of fuel. Many a time a new lot of good coal has been unjustly condemned as poor for steaming purposes, when it was simply unadapted for the grate, or the fire-box too high or too low—*generally too high.* For hard anthracite, 18 inches are sufficient fire-box height, 24 inches for semi-bituminous, and 30 inches for bituminous coal proper. In a 12-foot boiler, 48 inches in diameter, good usage sanctions the following dimensions and distances:

	Inches.
Height of centre line from ground,	80
Height of lower end of grate from ground,	varies
Length of grate, net,	55
Distance from top of grate to bottom of boiler,	varies
Thickness of bridge wall and mud-drum wall (if solid),	18
From centre of bridge wall to centre of mud-drum wall,	64

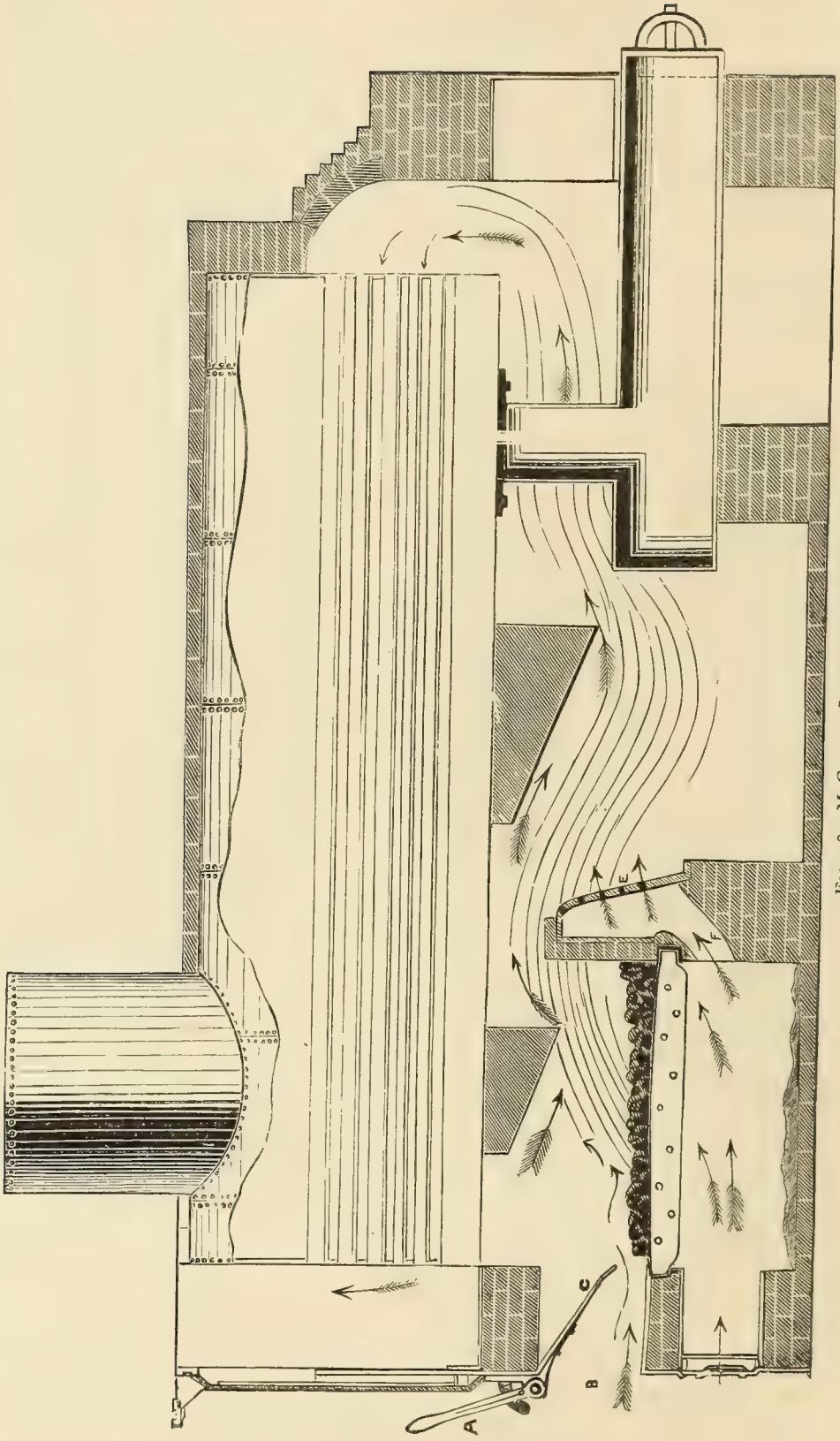


FIG. 58.—McGINNISS SMOKE CONSUMER.

	Inches.
Thickness of back cross wall { top,	3
Thickness of back cross wall { bottom,	19
Distance of centre of rear wall from centre of back cross wall,	29
Thickness of rear wall,	13
Height of rear cross wall,	51
Height of mud-drum wall,	varies
Height of bridge wall,	44
Depth foundation walls below ground level,	30
Thickness of side walls, if solid,	13
Side walls, out to out,	83
Side walls, in to in,	57

The boiler should be slightly inclined (say one inch in ten feet) toward the blow-off pipe at the back end, and this should be so placed as to drain

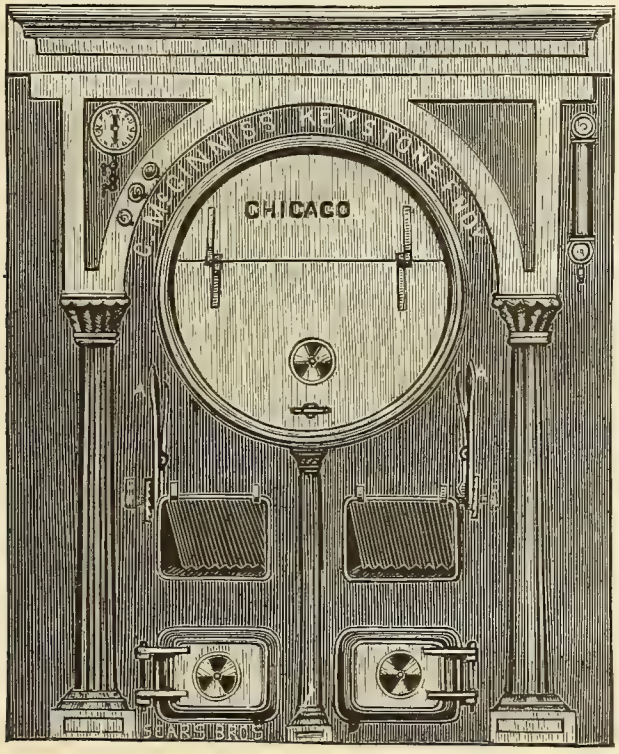


Fig. 59.—Boiler Front, with Smoke Consumer.

the boiler dry if needed. Long boilers should not be hung from three points; for, as they are heated more at the bottom than at the top, they will be expanded more on the bottom than on the top, and the ends will be thrown up, thus putting most of the weight upon the middle support.

Furnace Doors.—It is a good idea to have a swinging door just underneath the main furnace door, of which it may form a part. This will enable the fires to be sliced, without checking the steam capacity by opening the main door. Besides this, it shields the fireman from the intense heat of the fires.

Smoke Consumers.—Fig. 58 shows the McGinniss smoke consumer in section, and Fig. 59 the same in front view. This smoke consumer has an adjustable door, which can be raised or lowered by a lever, in front of the

boiler, and held in position by a pawl and ratchet, this door being to regulate the air supply. After firing up, it is set to suit the rate of combustion, and should require no further attention. This is the proper place to regulate the air supply, being better than back dampers. The door also deflects the air supply directly upon the flames. There are deflecting arches of terra cotta or other non-conducting material placed at intervals beneath the boiler, and serving to deflect the cold draft from the under surface of the boiler. The back wall of the furnace is hollow, and air is admitted through it from the ash pit and, entering behind the fire, improves the combustion. The current of gases of combustion from the grate passes under the first arch and through the second, which last is hollow, and through which enters a stream of fresh air which, by virtue of the action of the drop arch, becomes a counter current, and oxidizes the smoke in the gases of combustion. The proper dimension and position of this second arch are matters to be carefully determined. A member of a firm making such a device states that he has effected a saving of 21 per cent. of the fuel, and the manufacturer says that he is willing to warrant from 10 to 20 per cent., according to the circumstances, although in every case he guarantees 10 per cent. over the old system of plain furnace. The number of arches is proportioned to the length of the boiler, always with the same end in view—the deflection of the currents from the boiler surface. The price of this extra setting is about $150 per boiler.

Chimneys.—The chimney should have an area of about one-eighth that of the grate. If of wrought iron, it should be about twenty-five diameters high, and provided one-third of its length from the top with a wrought-iron band, to which are to be secured three guy rods; these are best made of wrought-iron rods linked together with welded rings or eyes; the diameters will vary from five sixteenths to one-half inch, depending upon the height and weight of the stack.

Cowls.—There are cases where the prevailing winds interfere with the draft of the chimney, and demand some appliances to accommodate the draft. For this purpose a cowl is generally used. It is so arranged that the opening for the escape of the smoke, which would otherwise blow down the chimney, is blown away from the direction of the wind. Cowls are used most where there is no one prevailing wind to contend with in this respect.

Steam Pipe.—Steam must be taken from the highest part of the boilers. because there it is driest. In large square boilers the dry pipe has several side branches. The best means of making the holes is by saw cuts. The large end must be plugged up. Sheet brass is the best material, as there is special liability to corrosion. Where dry pipes cannot be used by reason of making the inside of the boiler inaccessible, deflecting plates may be used. A small stop valve is apt to cause foaming. To remedy this it is better to add another stop valve at the other end of the boiler than to enlarge the existing one, because the new valve will draw steam from another point, and tend to equalize the pressure. The steam pipe should have expansion joints between all rigid fastenings. If there are no straight lengths which

can spring in case of expansion, the check valve should have as little lift as possible. With a high lift there is hammering and consequent destruction of the valve and seat, followed by leakage. One-half an inch should be the maximum check valve lift. The area should be enough to keep the velocity of the water under 600 feet per minute. To insure seating of the check in large valves, the upper valve spindle is carried through a stuffing box, and bears a weight which causes prompt seating. For small stop valves, between the check valves and the boiler, a plug cock is better than a globe valve, because it is less readily prevented from closing by solid matter getting in it.

The dry pipe, having numerous small perforations on its upper side, is inserted in the upper part of the steam space of the boiler. This pipe does not dry the steam, but acts mechanically by separating the steam and water when the latter is in a violent state of agitation and is liable to be carried in bulk toward or into the steam pipe. The object of these numerous small holes in the pipe is that a small quantity of steam may be taken from a large number of openings at one time, and thus carried over a larger extent of surface than that afforded by a single opening, this simple device checking the tendency to prime. This pipe, leading from the boiler, is sometimes carried through the combustion chamber under the boiler, and thence to the engine ; a practice not recommended under any ordinary circumstances.

Safety Valves.—The safety valve should be large enough to discharge at a given pressure, all the steam the boiler can make. It must close quickly when the pressure falls, by reason of its discharge below that point at which the valve is set to open. Each boiler should have its own safety valve, and each should be raised daily to prevent sticking. Both the valve and seat should be of gun metal to prevent rusting and sticking. The valve should be on top of the boiler, if possible ; if not, it should be connected with the highest part of the steam space. Every separate superheating chamber and feed-water heater should have a separate safety valve. The lever, where there is one, should be cut off at the point of maximum pressure, so that it will be impossible to move the weight farther out than allowable. Lock-up valves should be raised just the same as any other, else they are liable to be stuck fast. The best way is to have a cord running from the lever over pulleys so that the valve can be lifted from the front of the boiler. One trouble of the ordinary safety valve is that it has a limited action and its lift decreases with adjustment for high pressures. With a diameter of six inches it gives an area of less than one square inch. This necessitates large diameters with the accompanying large friction surfaces and corrosion.

Weighting may be accomplished either by applying the weight directly or by means of a lever. Coil springs are now very largely used for this purpose, and almost universally where the valve is directly weighted. Valve seats may be conical or flat. It is claimed for flat-seated valves, or disc valves, that they afford greater lift, are the simplest in construction, most reliable in action and the least liable to get out of order. A safety valve should be allowed to open occasionally, and not be excessively overloaded, and at least once each day, when in use, the valve should be opened by hand in order to

insure its perfect action. Valves which embody these advantages in an eminent degree are the Scovell Pop Safety Valves, illustrated herewith (Fig. 60). Simplicity is one of their chief merits. Although these valves differ materially in principle, they give very similar results under ordinary working pressures. The one which we first describe is more particularly calculated for stationary and marine boilers.

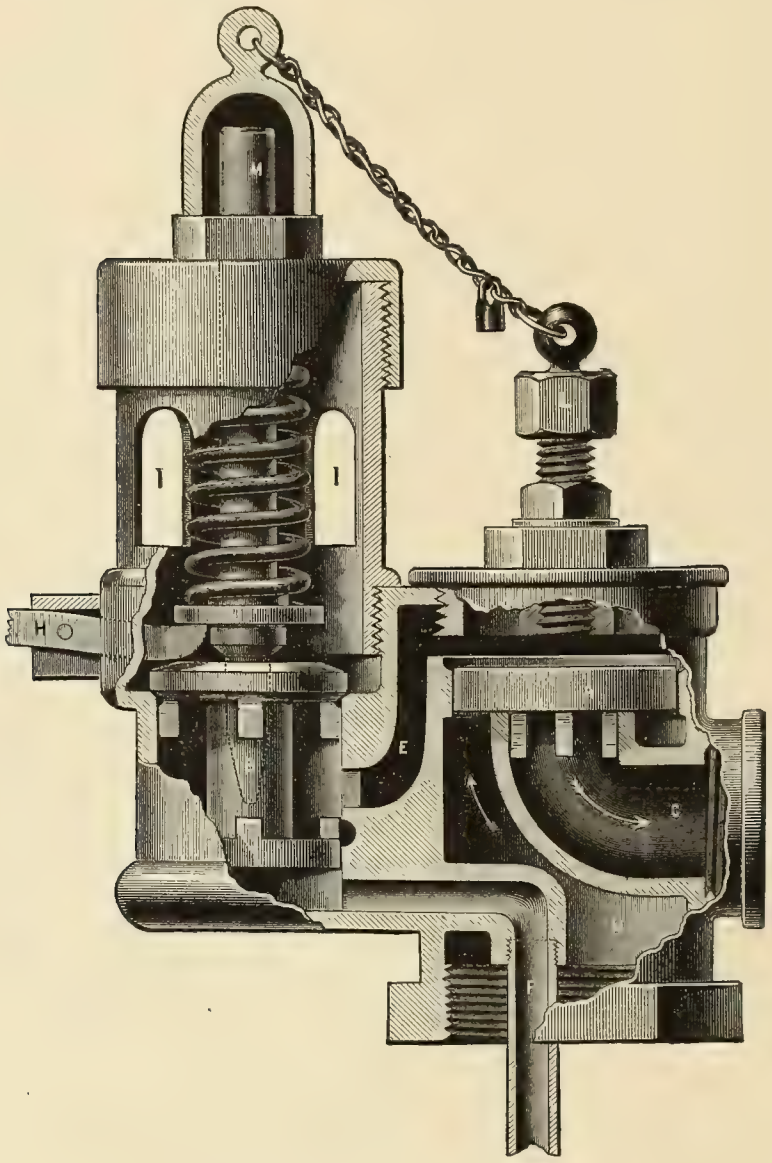


Fig. 60.—Scovell Pop Safety Valve.

The following is a description and mode of operation of this valve. The passage E forms the steamway between the valves A and B. The passage F conveys steam from the boiler to the valve B. The passage D conveys steam from the boiler to the main valve A. The set screw L is for the purpose of regulating the lift of the main valve A. The cap surrounding the spring spindle M regulates the tension of the coil spring. The lever H is for the purpose of opening the valves by hand. The openings I I are for the purpose of allowing steam to escape into the atmosphere from the valve B. The

elbow pipe C is for the purpose of allowing the steam to escape into the atmosphere from the valve A. The lock and chain secures the valve against being tampered with. The main valve A and lower disc of valve B are fitted so loosely in their cases that steam passes freely around and above them, constituting a counter pressure above the main valve A. The valve B, it will be understood, simply operates the valve A. The main valve A relieves the boiler. Atmospheric pressure acts upon the interior of elbow pipe C. The main valve A and lower disc of valve B are fitted so loosely in their cases that steam freely passes around and above them, forming a steam counter pressure or load above the main valve A, which holds it down on the top of elbow pipe C, which forms its seat. When the valves are at rest, their chambers are filled with steam at boiler pressure, and *at all times* the boiler pressure acts upon the lower disc of valve B and the annular space surrounding the seat of main valve A, but not so above them, as will be observed from the following description. The above description refers to the valve at rest, but we will now describe its action in "blowing off." As soon as the boiler pressure becomes greater than the resistance of the coil spring, the valve B is forced upward from off its seat. As this occurs, the steam pressure above the main valve A and lower disc of valve B begins to escape into the atmosphere through the seat of valve B and openings I I. The boiler pressure continues to increase slightly until the valve B has opened sufficiently to allow the steam load above the main valve A to escape through the passage E, and through the seat of valve B, and into the atmosphere more rapidly than it can get on top of and around the loosely fitted valves. The main valve A then opens to its full height, and relieves the boiler of its excessive pressure through the elbow pipe C, when the coil spring again forces the valve B back to its seat, causing the pressure to again accumulate in the chamber above the main valve A, and force it back to its seat on top of elbow pipe C. The trip lever H is so arranged that a downward pressure causes it to lift the spring and cause the valves to "blow off," but an upward movement of the lever will not exert any force on the valve to hold it down. The pressure can be easily changed at any time, by altering the tension of the coil spring with the cap screw.

It is claimed that the Scovell system of duplex valves gives many features of excellence, for the following reasons: Two valves are employed, as being highly desirable in severe and continuous service; Accuracy of operation does not depend upon any delicate adjustment; The seats are of the simplest form, and can be reground by any ordinary workman without impairing the efficiency and accuracy of the valves' action. No pressure accumulates after the valves open, and they close with a slight reduction of pressure.

The safety valve, of which every boiler ought really to have two, should have an area of at least 1 square inch for each 2 square feet of grate surface. Another rule, ascribed to Professor Thurston, is to multiply the pounds of coal burned per hour by 4; this product is to be divided by the steam pressure, to which a constant number 10 is added.

Example: What would be the proper area for a safety valve for a boiler having a grate surface 5 feet square and burning 12 pounds of coal per hour

per square foot of grate; the steam pressure being 75 pounds per square inch?

$5 \times 5 = 25$ square feet of grate. $25 \times 12 = 300$ lbs. of coal per hour. $300 \times 4 = 1200$.

$75 + 10 = 85$ = steam pressure with 10 added, then $1200 \div 85 = 14.11$ inches area or $4\frac{1}{2}$ inches diameter.

Fractures, blisters, internal corrosion, internal grooving, sediment, scale, deposit are in no way under the control of the safety valve.

The safety valve is often overloaded to save steam. An explosion occurred in Mississippi, in 1871, by which four men were killed. The following account tells the whole story: "The day previous to the explosion the safety valve was leaking. Instead of grinding down the valve a piece of gum packing was placed under it. This blew out; a new piece was put under, and then a brace was placed between the valve lever and the roof of the building to hold it down and retain the packing. Having thus got things well in train for a first-class blow up, the engineer got up steam, running the pressure up to 105 pounds, 'the last time he looked at the gauge'. He thinks there were two gauges of water, but is not sure, as two men were pumping in water at the time of the catastrophe. That two men were required to work the pump shows that this was out of order. In short, there was no one about the establishment that seemed to know much about anything, more especially steam, and, as a consequence, destruction swiftly followed their silly tinkering."

Fusible Plug.—The fusible plug is made of some alloy melting at a very low temperature, it is placed in a hole in the boiler usually a little above the danger level; when uncovered by water it is melted and the discharge of steam at once relieves the pressure and gives the alarm.

Pressure Gauges.—These should be tested every three months by a mercury column, so that it may be known whether they are right or not. There are plenty of incorrect steam gauges; sometimes the gauge was incorrect to start with, sometimes it has been neglected or injured. Inspection shows gauges varying from 40 pounds below to 60 pounds above the real pressure. The former case, of course, is one of extreme danger, because the gauge may have shown 100 pounds only when there were 140 pounds on. The practice of placing a stop valve between the boiler and safety valve cannot be too severely censured. It is a dangerous trap, even in the hands of a competent man.

Glass Water Gauge.—A glass water gauge should be on each boiler; its lower gland on a level with the lower gauge cock. Gauge glasses should be large, so as not to be easily clogged by pieces of loose scale or other impurities in the water. An improved gauge glass has the back of the tube of white enamel, the front being transparent. This renders the water level more easily seen. When the boilers foam badly, the gauges do not easily indicate the height of solid water.

Draft Regulator.—This apparatus has the advantage of saving fuel, increasing boiler capacity, preventing excessive smoke, and keeping steam even. In addition, it lengthens the life of the boiler.

Feed Pipe.—The feed pipe is commonly screwed into a hole tapped in the back boiler head. To allow for clogging, sediment and scale, it should have an area double that requisite to pass the quantity of water. When the water is hard it should be disconnected from time to time to see that it is not filling up with crusts. Make the feed pipe short, straight and above ground.

Where to put the Feed Pump.—The question has been asked whether the feed pump ought to go between the heater and the boiler, or before the heater, so that the latter will heat its discharge. As the feed pump will not lift very hot water, the heater must be placed between the pump and the boiler in those cases where the feed is not heated by direct contact with the steam. A pump will force hot water as well as it will cold. If the feed-water is taken from a stream in which there are floating particles of wood, leaves, etc., a strainer should be used. A large sheet-metal box with perforated sides makes a good strainer. The openings ought not to greatly exceed an eighth of an inch in diameter, and should be several times the area of the suction pipe. The feed pump should be four times large enough to run the boiler; and the speed should be proportionately reduced. Feed pumps sometimes give trouble by intermittent action, working well enough for a few days and then stopping wholly or from time to time. This happens very often because of bends in the pipe, in the upper portion of which air collects.

No one yet seems to have been able to say why it is that when the pump fails to work, a hammer is generally taken to start it up. It requires only a very small leak in a pump or in its connections to overcome the vacuum and stop the pump from working. If pump valves have spindles as guides, these should fill the holes and the seats should be straight lines, not curves. Valves that do not fit are apt to cock on their sides and leak. All boilers should be fitted with a cock between the check and the boiler, so that the check can be examined. Valves fitted with wings are apt to bind in their seats and stick fast. All pumps should be as close as possible to the source of supply. The higher the speed the shorter the lift on the feed side may be. Bear in mind that water is not compressible, and do not attempt to force it against closed cocks or valves.

The Hancock Inspirator consists of a double apparatus in one casting, in one serving as a lifter, which raises water and delivers it to the other half, which forces it to the boiler without adjustment being needed for varying steam pressure. There are certain conditions about almost any good jet apparatus for boiler feed which are possessed in a high degree by the inspirator. There are no valves or movable parts to break or get out of order. All of the steam used to force water is condensed in the water, not only adding to the volume of feed-water, but heating it, and thus saving fuel and doing away with the cost of a heater. There is no oil needed. The inspirator will lift water twenty-five feet, with forty-five pounds steam pressure, and deliver it into tanks or in the boilers. It will take water as hot as 140° on a lift of three or four feet or under a head, and on a lift of twenty-five feet it will take it at 100° to 110° F. The temperature at which it will deliver the water

depends upon the steam pressure, the temperature of the water drafted and the quantity of steam used upon the forcer side. The higher the steam pressure, the higher the water would draft, and the more steam left in on the forcer side, the higher will be the temperature at which it will deliver water. With fifty or sixty pounds steam pressure, and about one-quarter turn of the handle on the forcer side, the water will be delivered from 160° to 190° F. The temperature of the water delivered may also be increased by giving more steam on the starting valve, or by throttling the water supply. The

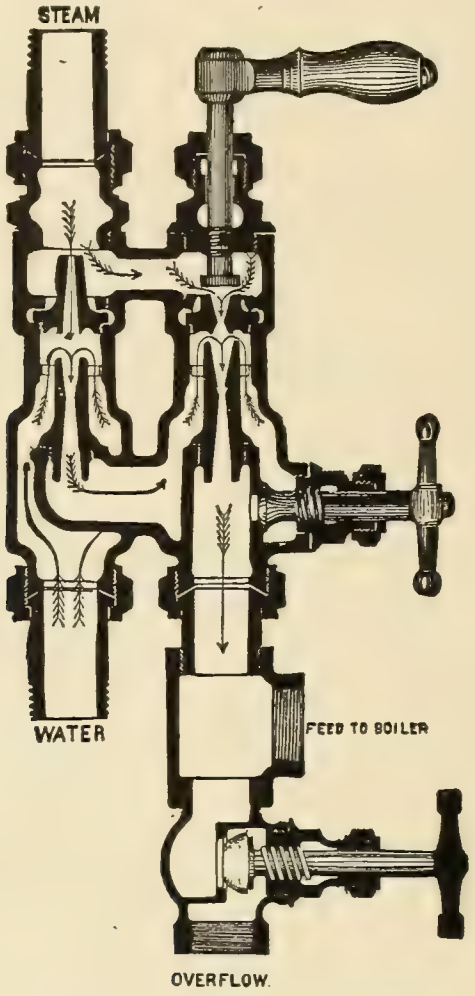


FIG. 61.—SECTION OF HANCOCK INSPIRATOR.

lifter side alone will lift water twenty-four feet, and deliver it twenty feet above the apparatus, with forty pounds of steam, heating the water at 20°. With the lifter and forcer together it may be said that the water can be forced two feet above the inspirator for every pound of steam pressure.

In applying and running the inspirator, care should be taken that the suction is tight, so as to give a good vacuum; that the steam comes direct from the boilers, and from that portion of the boiler where it will be dry steam. Taking steam for the inspirator from the steam pipe has the disadvantage that the steam will not be so dry as if taken from the boiler direct; and, further, that if this steam pipe supply an engine cylinder, the supply to

the inspirator will be apt to be irregular. Where it is absolutely necessary to tap a steam pipe, it should be tapped upon the upper side so as to avoid drainage. An inspirator cannot be run with hot water. In starting, any water that may be in the steam pipe must be let run off at the overflow. Sometimes the suction gets full of hot water. In this case it will be necessary to cool the inspirator and suction with cold water, or, better yet, to let the steam on and off suddenly at the starting valve until all the hot water is disposed of. As the friction of a long draft increases the quantity of water drawn, it will be best to have the suction pipe two or three times greater in diameter than the connections. The capacity of the injector should be such that it will deliver water just as fast as the steam is called for, so that it will be running constantly. The cut shows the inspirator in section. It must be remembered that the inspirator effects a considerable economy of fuel over feeding cold water, and also where the water supply is hot and regular, as with the proper size inspirator, there is no injury to the boiler from contraction and expansion of plates, as is the case where cold water is pumped in spasmodically.

Steam Traps.—There are three kinds of steam traps. The expansion trap is of two kinds, one composed of metals expanding differently under heat (as brass and iron), the other depending on the expansion of a liquid. As condensed steam is cooler than live steam, it closes the most expansible of the two metals so as to open a passage for the water. If there is a liquid to be expanded, live steam cools the orifice, and condensed steam opens it. The functions of a good pot trap must be to discharge the water of condensation from coils or from the cylinder of an engine into a tank or sewer at a higher level than that which it drains, keeping the coils of the cylinder dry. To be of real economy, a trap should discharge the water of condensation back into the boiler. The pot trap is not economical by reason of its not discharging water down to atmospheric temperature and pressure under any condition of temperature of the water in the coils due to high pressure.

The Blow-off Valve.—The blow-off valve should be very tight, or there will be danger of its leaking every night, and thus emptying the boiler. It should enter the boiler so low down as to drain all the water when necessary. It should have a reliable valve, and should have its outlet in view, so that any leak in the valve can be seen. It must not be forgotten to close the blow-off.

Boiler and Pipe Covering.—No reputable engineer will allow his boiler and pipe to remain uncovered, for he is reducing the capacity and the duty of both engine and boiler by allowing the waste of heat by radiation. There are many kinds of coverings in the market; those giving the best results employing a non-conducting material, with air space. In buying covering for boiler and pipe, especially for the latter, take care to get one that will have as many as possible of the following points: Lightness, to save freight and to prevent weighing the pipes down; ease of application and removal; freedom from cracking and crumbling; low heat-conducting power and low cost; and it is perhaps an advantage if it can be put on the

pipes when they are hot. For low temperatures, such as occur on ordinary mill boilers, the Toope Sectional Covering, Fig. 62, made by Chalmers-Spence Company, N. Y., may be recommended. It consists of layers of hair felt, alternating with asbestos inside and out, being made in sections three feet long, split down one side so as to be easily applied, and the joint being fastened by wire staples or by copper wire, and then pasted over with paper. The covering should be larger than the pipe, and should be held off at an equal distance all around by short collars of the same material, breaking joint with the lengths. Fig. 63 shows another form of covering made by the same company, but not sectional.

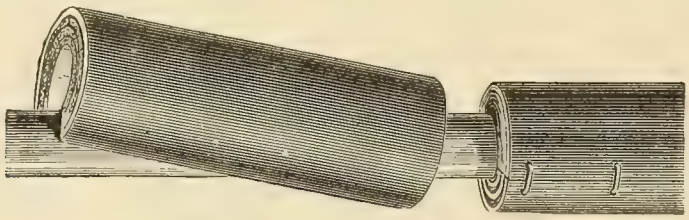


FIG. 62.—"TOOPE" SECTIONAL PIPE COVERING.

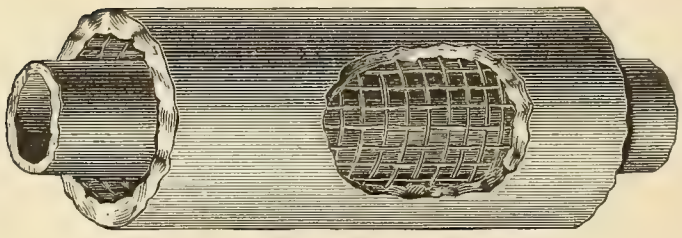


FIG. 63.—"AIR SPACE BOILER AND PIPE COVERING.

Experiments made by the author with this covering on $2\frac{1}{2}$ inch steam pipe of Newton Machine Tool Works, Philadelphia, and others, show as follows:

	Average Pressure of Steam, lbs.	Average Temperature of Steam Pipe, Fahr.	Average Temperature of Covering.	Average Temperature of Room.	Relative Non-conducting Values of Covering.
Asbestos and Hair Felt (Toope), 1 in. thick, 1 in. air space,	$36\frac{1}{2}$	$268\frac{1}{12}$	$115\frac{1}{2}$	90	1.0000
Asbestos and Hair Felt (Toope), 1 in. thick, no air space,	$41\frac{1}{6}$	$264\frac{8}{8}$	$127\frac{1}{3}$	91	0.8952
Sectional Plaster, 1 in. thick, 1 in. air space,	44	$259\frac{3}{3}$	$173\frac{3}{4}$	85	0.7433
Asbestos Cement, 1 in. thick, no air space,	$47\frac{5}{12}$	270	$158\frac{1}{12}$	$91\frac{7}{12}$	0.8039

The figures given above are the averages of twelve readings.

Blowers for Boilers.—A correspondent of the Boston *Journal of Commerce*, who had been investigating the subject of blowers for steam boilers, gives the following as the result: "From my investigation and experience I have arrived at the following conclusions: Upon inquiries at the largest manufactories, I found that there are more blowers now being used for boiler purposes than ever before, and that their use for that purpose is steadily increasing; that the power required to run a blower for such purpose is small as compared with the benefits obtained in increased boiler capacity and the ability to use a cheaper class of fuel; that there is small risk from fire if properly put up and used. During several years' use of a blower, and from inquiries made of those using for the same purpose, I can learn of no instance of back draught occasioned by its use. (The mill adjoining me using no blower, was set on fire by back draught.) There will be no blow-pipe action if the air is properly put into the ash pit and regulated by a gate, and the effect on the crown sheet will be the same as with strong natural draught. It is not an uncommon occurrence to be obliged to renew the crown sheet when blowers are not used. Certainly something must be wrong and out of the usual course to be obliged to renew them on new boilers in so short a time. In conclusion, my own experience demonstrates that to offset the disadvantages of a blower, if any, a saving is made of fifty per cent. in fuel expenses by my ability to use a cheaper class of fuel, although I have a good natural draught from a 100-foot brick chimney."

Heating and Filtering Feed-Water.—No matter what means are employed to feed a boiler, steam pump, power pump, or injector, it is essential that the feed be constant and exactly equal to the steam generation, and desirable for many reasons that it should be pure and hot. The heater has for its office reclaiming from the gases of combustion, or from the exhaust steam, heat which would otherwise pass off unutilized. To change one pound of water at 32° into one pound of steam at 60 pounds pressure on the gauge (or 75 pounds total at 307½°) requires 1175.2 heat units. From water 28° degrees hotter, or 60° F., it takes only 1147.2 units. If we could feed in water at 200°, we would gain another 140 units, requiring only 1007.2 in all. Where exhaust steam can be used for this purpose, it is so much clear saving in coal, to say nothing of other advantages, such as avoidance of sudden chilling of the contents of the boiler and contractions of its shell, &c. The table on following page shows the percentage of saving in fuel by heating feed-water, in raising steam at 60 pounds.*

Fresh water feed is either soft—that is, nearly pure, as shown by its leaving no deposit on being evaporated on a plate of glass—or hard, that is, containing in solution mineral substances, as carbonate of lime (chalk, limestone, marble), or sulphate of lime, sulphate of magnesium, salt, &c. Feed-water may also contain in suspension undissolved matter, as mud, sawdust,

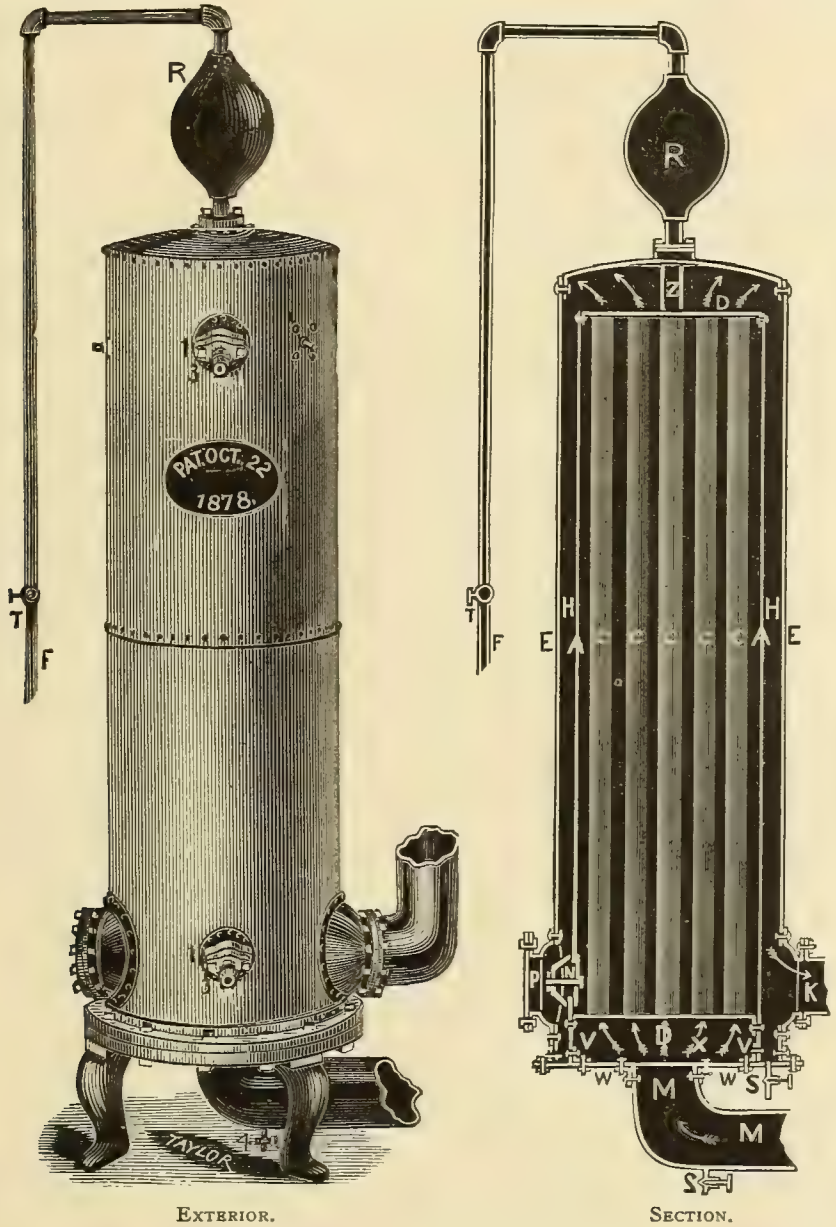
* Engineer Nystrom, in his work on Steam Engineering, page 54, places the saving of fuel by heating feed from 62° to 100°, at 4.4 per cent.; to 200°, at 17 per cent., and to 212°, at 18 per cent.; this being in the case of steam of eighty pounds boiler pressure, shown on the gauge; but these figures represent the maximum, and do not cover the ordinary practise of feeding in the water leg, where the feed does not *undo* the work of evaporation.

sand, &c. The limy carbonates are the most widely spread and abundant, and when the dissolving water is heated to 212° they are precipitated, being generally deposited on the bottom and sides of the boiler shell and tubes, on the tops of the flues, and in water legs. For this reason tubular boilers should be avoided in lime water districts. This deposit causes leakage at seams, fracture at plate edges, overheating and softening, or even burning of the plates. The use of animal oils as cylinder lubricants where they are liable to get round into the boiler, *via* the feed heater, makes the deposit spongy and tough. The loss of heat by the accumulation of scale by this means is proved to be about as follows: 1-16″ scale requires extra heat corresponding to 15 per cent. of fuel; ¼″ scale requires extra heat corresponding to 30 to 60 per cent. of fuel; ½″ scale requires extra heat corresponding to 60 to 150 per cent. of fuel. The danger of explosion, the frequent priming and foaming of the boiler, causing grit to work over into and cut the steam chest, slide valve, cylinder and piston, and the frequent stoppages for repairs or examinations, render it extremely desirable to remove the cause of incrustation by filtering out mechanically-held impurities and precipitating those chemically dissolved. If, now, we can have a device which will not only remove the undesirable foreign bodies, but, in so doing, effect an economy by heating the feed, we shall be largely the gainers.

Final Temperature.	Initial Temperature of the Feed-Water.												
	32°	40°	50°	60°	70°	80°	90°	100°	120°	140°	160°	180°	200°
60°..	2.39	1.71	0.86	...	...	...	...	...	...	..	..	..	..
80°..	4.00	3.43	2.59	1.75	0.88	...	...	...	...	..	..	..	..
100°..	5.79	5.14	4.32	3.49	2.64	1.78	0.90	...	...	..	..	..	..
120°..	7.50	6.85	6.05	5.23	4.40	3.55	2.68	1.80	...	..	..	..	..
140°..	9.20	8.57	7.77	6.97	6.15	5.32	4.49	3.61	1.84	..	..	..	..
160°..	10.90	10.28	9.50	8.72	7.01	7.09	6.26	5.42	3.67	1.87	..	..	..
180°..	12.60	12.00	11.23	10.46	9.68	8.87	8.06	7.23	5.52	3.75	1.91	..	..
200°..	14.30	13.71	13.00	12.20	11.43	10.65	9.85	9.03	7 36	5.62	3.82	1.96	..
220°..	16.00	15.42	14.70	14.00	13.19	12.33	11.64	10.84	9.20	7.50	5.73	3.93	1.98
240°..	17.79	17.13	16.42	15.69	14.96	14.20	13.43	12.65	11.05	9.37	7.64	5.90	3.97

Baragwanath's Feed-Water Heater.—There is no difference of opinion among engineers about the desirability of having pure feed-water and of having that feed-water hot; but while all agree that the feed should be pure and hot, all are not agreed to the best method of heating and purifying, and few really think just how great the saving and advantage are. About this thing they do agree: that the purer a feed-water, the better it is, and that the hotter the feed, the greater the saving. It has been found that the best way to free the water from certain chemical impurities actually dissolved in it is to heat it to the boiling point. This is at least true of most waters, and especially true of those containing carbonates of lime and kindred chemical substances. This heating may be done either by employing the waste heat of the gases of combustion, by using live steam, or by exhaust steam.

Sometimes it is done by passing the feed-water through a coil running through or alongside of the combustion chamber. The best way is to employ the exhaust steam, if it can be used so as not to produce back pressure upon the engine. The mistake should not be committed of having the heater too small, and in every case there should be some arrangement by which the



EXTERIOR. SECTION.

FIG. 64.—FEED-WATER HEATER.

mechanical and chemical impurities may be collected when dropped, and blown off when desired. Under the head of incrustation and corrosion, we have shown the loss of fuel by allowing scale or sludge to collect in the boiler, to say nothing of the great danger to the boiler. The form of heater shown herewith (Fig. 64)*, known as the "Steam Jacket Heater and

* Made by Baragwanath & Pim, Chicago.

Purifier," consists of an outer shell, A A, with heads, D D, between which flues, C C C, extend. There is an outer jacket, E, leading a space, H, between it and the inner shell. Both the heater and the jackets are secured to bed plates, W W. There is a scum chamber, R, with proper blow-off, F F. The cold and impure feed-water is let in through the lower pipe and passed to the boiler through the upper pipe. The exhaust steam enters the chamber V V, through pipe, M M, and passing through the flues C C C, descends through the steam space H H H, passing off through the exhaust pipe K. P is a nozzle for reaching the plate N. The condensed water falls to the bottom, and may be removed by the drip-cock S, although it would be much better if it were to be mingled with the feed, except in those cases where the cylinder is lubricated with animal oil, in which case the condensed steam should not be allowed to enter the boiler.

Feed-water is most liable to be muddy in the spring and fall, when there is more surface and muddy water running in and mixing with it. In the West the feed-water makes more scale in dry weather than in wet, as it contains less rain water. One of the muddiest sources of feed-water is the Chicago river and its tributaries. In the northern part of Wisconsin and the Lake Superior region the water is soft.

Corrosion.—It frequently happens that where water is too pure to form any scale in boilers, it contains acid impurities rather than salts. These impurities cause internal corrosion. Besides, external corrosion takes place from many causes, as setting in too much impure lime, setting on damp, undrained foundation, allowing cold ashes to remain in contact with the iron, &c. Where wood is freely used the soot in the tubes and flues gets charged with pyroligneous acid, as is also the case where coal is freely changed. Sulphurous coal also corrodes the external surfaces. Corrosion is sometimes caused by galvanic action of brass connections attached directly to the iron shell, and this is hastened by leakage at their junction. It is proved beyond all question that perfectly pure water rapidly corrodes boilers, especially those of wrought iron. A most common cause of corrosion, as well as of other evils, is the introduction of animal oils, such as work in with the exhaust steam through the feed heater, and from jet condensers oleic acid is formed and attacks and dissolves iron, especially where lime is present to form a soap which sticks to the boiler walls.

External corrosion is generally caused by the exposure of boilers to the weather, sometimes from leaky joints, droppings, and carelessness in allowing the water to run down underneath on blowing down, particularly when internally fired. All of these wear away the boiler and shorten its life. Where boilers are entirely bricked in, external corrosion is hard to detect. Wood ashes should never be allowed to touch the boiler plate, especially on top, as any water dripping through leaches out a destructive alkaline salt. Ashes should not be allowed to accumulate, particularly in internally fired boilers. They are bad enough when dry, worse when wet. To prevent external corrosion it should be seen that the boiler seams and man-hole plates are tight, and that all attachments and steam pipes are free from leaks. Internal corrosion looks very much like ordinary rust. If a boiler

is covered with scale there are apt to be red streaks wherever there is a crack.

Internal corrosion attacks the edges of plates at the joints and at the rivets. Sometimes it shows itself as a pitting of the plates like small-pox. It is very uneven in its action. When found in connection with scale, the boiler should be kept free from scale and as clean as possible by blowing the water out. If there is free acid in the water, the water should be abandoned. If this cannot be done, the acid should be neutralized by some harmless alkali, as soda or soda ash, introduced with the feed. This should be used only where the water is acid, and where it is used the boiler should often be inspected to see that there is no harm being done by the combination of the alkali with other things in the water.

Grooving.—This is found running parallel with the lengths of the seams, close to the edge of the inner lap, also following the inner lap of girth seams. It results, in most cases, from straining and fretting the iron where there is unequal expansion in connection with impure feed-water, the skin getting cracked and the water attacking the inner layers of the plates. This cracking may be caused by improper setting or by unequal heating. There is more trouble from this cause where there is imperfect circulation.

Incrustation.—When water contains only three per cent., by weight, of saline matter, no deposit takes place at the boiling point, under atmospheric pressure or at 212°. When it contains ten per cent., it deposits lime, principally sulphate. Common salt is deposited when there is 29.5 per cent. of it. At high temperatures, deposit takes place at less per cent. This is one reason why marine boilers have to carry low pressure, expanding at low temperature. In marine boilers there is great loss of heat by blowing off. If the water entering the boiler is at a density of 1.32, and that of the boiler maintained at 2.32, one part will be made into steam and one part will be blown out. If the water enters the boiler at 100° F., and the water is at 248° at each temperature, the total heat is 1189.58°, then there will be 1089.58° to be got from the fuel, and there will be 148° lost by blowing off. The loss is

$$\frac{1089.58+148^\circ}{148^\circ} = 11.95 \text{ per cent.}$$

The lower the density, the less the loss by blowing off, and vice versa.

To knock the scale off of the places which are within reach, sharp-faced scaling hammers are used, and long scaling bars, flattened at both ends, to reach more distant places. Scaling boilers, by heating up high with shavings and then pumping in cold water, is highly injurious, and causes leaks. To lessen corrosion from soot in the flues, as well as to increase the duty and lessen the fuel consumption, the flues should be swept. This is a very disagreeable operation, unless the soot and ashes are first sprinkled with water.

If you consider the large amount of water evaporated in a long run of a boiler, and the great amount of scale or sediment that it will contain, the Croton water is comparatively pure; but a 100 horse-power boiler which evaporates 30,000 lbs. of water in ten hours, will, in one month, evaporate 390 tons, in which there will be 88 lbs. of solid matter. In many kinds of

spring water there will be, or in this 390 tons, as much as 2,000 lbs. of solid matter. The Railroad Master Mechanics' Association of the United States estimates that the loss of fuel, cost of extra repairs, &c., due to incrustation, amount to an average of $750 per year for every locomotive in the Middle and Southern States.

Characters of Scales.—Carbonate of lime appears as chalk, common limestone and granular marble. As it percolates in the soil the carbonic acid dissolves it, making the water hard, but when the carbonic acid escapes, the lime begins to be deposited. Carbonate of lime usually deposits as a fine powder, forming a whitish slush or sludge with the water. Carbonate of magnesia behaves in about the same way. If in large quantities, carbonate of lime remains soft for some time, if not heated too high. If boilers are properly cooled before being blown off, the carbonate of lime will be found as a fine powder, but if blown off while the plates, brickwork and flues are greatly heated, the sludge becomes baked hard on the plates. Soft deposits injure the boiler as well as hard. When the water becomes saturated with this material, there is a resistance offered to the escape of the steam bubbles and to the free conduction of heat. The deposit collects upon the bottom, around the seams, and, in fire-box boilers, around the furnace sheets and around the water legs. Its presence is shown by leakage of the seams, fractures at the edge of the plates and in the line of the rivets, and by overheating and consequent depression of parts of the plates where it rests. Where grease finds its way into the boilers this trouble is increased, hence open feed water heaters, into which the exhausted steam from the engines is discharged with no provision for separating or extracting the grease or lime from the water, are to be used with caution. Sulphate of lime is heavy, and hence is not long held in suspension. It deposits, forming one of the most troublesome scales that is known. Scales having a reddish tint owe this to presence of salts of iron. Water from iron districts, and in the vicinity of mines, and on the sides of mountains gives this scale. Sometimes that from artesian wells yields it, sometimes it turns up where least expected, where it has percolated through some iron bogs. This scale injuriously affects the iron plate. The water that gets behind it has the appearance of blood, and when the boiler thus "bleeds," the scale should be removed at once. When there is much trouble from carbonate of lime, frequent blowing down an inch or two will be of use. If the impurities show at the gauge cocks and fur them, the surface blow should be used. Never, under any circumstances, blow down a boiler when hot and under working pressure. It ought to be enough to say this, but perhaps it will be better to state the reason why, under these circumstances, a quantity of the suspended impurities lodges on the tubes and flues and finds its way into the water legs, then it burns, forming a hard scale that must be chipped off with hammer, chisel and pick. There are many boilers in which the scale has been formed entirely by reason of injudicious blowing down. They should be let cool; the fires should be drawn, the furnace doors opened, till all is well cooled down—then the blow may be opened The slush or sludge should then be removed, and the boiler washed out with a hose.

There are substances employed in removing or preventing scale which are effective in doing this, but injure the water. Among these we may class the barks of oak, hemlock, &c., sumac, catechu, logwood, &c. They will remedy scale in waters containing carbonates of lime or of magnesia, but they are injurious to the iron. It must be remembered that well waters containing bicarbonate of lime may be made to deposit this mineral by simply heating them to 212°. This process has no effect upon any other kind of impurities. We find molasses, cane juice vinegar, fruits, distillery slops, &c., used with success as far as removing the scale is concerned, but the acetic acid which they contain, and which is the active principle in removing the scale, is even more injurious to the iron than tannic acid. The action of soda ash with water containing sulphate of lime is to convert it into carbonate, which gives a scale easily cleaned. If used in excess it causes foaming, especially where there is oil coming from the engine, in which case they form soap. Petroleum has been recommended for waters which contain sulphate of lime, but unless very well refined it forms a crust. It is well, however, to purchase a regularly manufactured anti-incrustator, such as that made by George W. Lord, 316 Union street, Philadelphia. Potatoes and slippery elm are of use in many cases, as the starch or gummy matter which they contain envelops the solid particles and throws them down. The action is analogous to the clearing of coffee by the white of an egg. Catechu and other astringents are of use in limy water, but where they are used frequent blowing and surface blowing is necessary, otherwise the iron will be injured. Crude petroleum, that is, unrefined earth oil, is quite good for water containing sulphate of lime, but not so good against carbonate of lime. When such purgers are used, the boiler should be often opened and cleaned, because scale lying in a heap upon the bottom of a boiler tends to ruin the boiler almost as much as if baked on hard.

In asking expert advice as to scale in your boilers, or in ordering incrustators, you should give the following details and send the sample of boiler scale—enough to cover a "nickel" is sufficient. If you have no sample of scale describe the nature of it. Send also a rough sketch of the boiler, showing the fire end of the boiler (if horizontal), also the exact location of the blow-off pipe, and how it is arranged. Particulars are of importance in giving proper advice. Details: How many boilers; what kind of boilers; horse-power of each boiler; entire boiler capacity; how much steam you carry; if the boilers have plenty of steam room; what is the character and source of the feed-water; how often you change water and get rid of sediment; where the blow-off is; how often you open the blow-off; how long you keep it open; thickness of the boiler scale; if the scale is very hard; if it is closely formed, or porous; if you feed from a tank; if you use a heater—if so, what kind of a heater; if the feed-pipe clogs up or forms a scale; what kind of fuel you use; if you run day and night, and if you run seven days in the week. A bottle of the water should be sent if possible.

Flue Cleaners.—Flues should be kept cleaned from soot and fine ashes, which not only prevent the proper passage of heat to the water on the other

side, but cause corrosion by reason of the acids that they contain, especially where wood is used as fuel. A convenient form is that made by the Chalmers-Spence Company, N. Y., and shown in Fig. 65. It will be seen that it can be readily adjusted to tubes of different diameters. The working parts are of steel, and it should do better work than brushes.

Management.—Perhaps there is not enough attention paid about the mill to the exactness of how long the boilers and engine are to last in good condition. It is one thing to get as much steam from as little grate surface and heating surface as possible, and another to keep the boiler for ten or fifteen hours in good condition. There are many boilers that are forced so much that they soon give out. Sometimes a little is saved in original outlay for boilers, or perhaps in the matter of fuel, but in many cases this is saving at the spigot and wasting at the bung-hole.

To cool down an overheated boiler, the ordinary and incorrect way is to open the furnace doors, and if the water is low to start the pump. This causes sudden cooling of the plates, tubes and flues, and renders them liable to fracture, especially riveted joints from the rivet hole to the edge of the plate and along the line of rivets from hole to hole.

It sometimes happens that, after the fires are covered for the night, the pressure in the boiler rises and opens the valves. This is caused by the hot masonry imparting its heat to the boiler.

Boiler fittings and appliances are apt to get into very unreliable con-

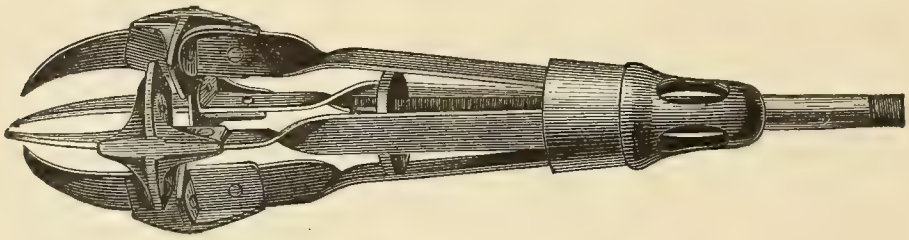


Fig. 65.—Flue Cleaner.

dition from negligence, An ignorant man who expects that, when the water gets low in his boiler, the whistle will blow and a pump start automatically, will get into the habit of depending upon these signs, and some day the signal will fail to be given, and damage or disaster will result.

Rules for the Management of Steam Boilers.—Engineers and users of steam power will be benefited by keeping constantly in mind the following rules:

1. Condition of the Water.—The first duty of an engineer, when he enters his boiler-room in the morning, is to ascertain how many gauges of water there are in his boilers. Never unbank nor replenish the fire until this is done. Accidents have occurred, and many boilers have been entirely ruined from neglect of this precaution.

2. Low Water.—In case of low water, immediately cover the fire with ashes; or, if no ashes are at hand, use fresh coal. Do not turn on the feed under any circumstances, nor tamper with, nor open the safety valve. Let the steam outlets remain as they are.

3. In Case of Foaming—Close the throttle, and keep closed long enough to show the true level of water. If that level is sufficiently high, feeding and blowing will usually suffice to correct the evil. In case of violent foamings, caused by dirty water, or change from salt to fresh, or *vice versa*, in addition to the action above stated, check draft and cover fire with fresh coal.

4. Leaks.—When leaks are discovered, they should be repaired as soon as possible.

5. Blowing Off.—Blow down, under a pressure not exceeding 20 lbs., at least once in two weeks; every Saturday night would be better. In case the feed becomes muddy, blow out six or eight inches every day. Where surface blow-cocks are used, they should be often opened for a few moments at a time.

6. Filling up the Boiler.—After blowing down, allow the boiler to become cool before filling up again. Cold water pumped into hot boilers is very injurious, from sudden contraction.

7. Exterior of Boiler.—Care should be taken that no water comes in contact with the exterior of the boiler, either from leaky joints or other causes.

8. Removing Deposit and Sediment.—In tubular boilers the hand-holes should often be opened, and all collections removed from over the fire. Also, when boilers are fed in front and blown off through the same pipe, the collection of mud or sediment in the rear end should be often removed.

9. Safety Valves.—Raise the safety valves cautiously and frequently, as they are liable to become fast in their seats and useless for the purpose intended.

10. Safety Valve and Pressure Gauge.—Should the gauge at any time indicate the limit of pressure, see that the safety valves are blowing off.

11. Gauge Cocks, Glass Gauges.—Keep gauge cocks clear and in constant use. Glass gauges should not be relied on altogether.

12. Blisters.—When a blister appears, there must be no delay in having it carefully examined and trimmed or patched, as the case may require.

13. Clean Sheets.—Particular care should be taken to keep sheets and parts of boilers exposed to the fire perfectly clean; also all tubes, flues and connections well swept. This is particularly necessary where wood or soft coal is used as fuel.

14. General Care of Boilers and Connections.—Under all circumstances keep the gauge cocks, &c., clean and in good order, and things generally in and about the engine and boiler-room in a neat condition.

The *American Machinist* puts the following

Pertinent Questions:—How long since you were inside of your boiler? Were any of the braces slack? Were any of the pins out of the braces? Did all the braces ring alike? Did not some of them sound like a fiddle string? Did you notice any scale on flues or crown sheet? If you did, when do you intend to remove it? Have you noticed any evidence of bulging in the fire-box plates? Do you know of any leaky socket bolts? Are any of the flange joints leaking? Will your safety valve blow of itself,

or does it stick a little sometimes? Are there any globe valves between the safety valve and the boiler? They should be taken out *at once*, if there are. Are there any defective plates anywhere about your boiler? Is the boiler so set that you can inspect every part of it when necessary? If not, how can you tell in what condition the plates are? Are not some of the lower courses of tubes or flues in your boiler choked with soot or ashes? Do you absolutely know, of your own knowledge, that your boiler is in safe and economical working order, or do you merely suppose it is? These are questions of great importance.

CHAPTER X.

THE STEAM ENGINE.

Steam — Mechanical Effect — Expansion—Throttling and Wire-Drawing — Back Pressure — Economy of High-Pressures — Condenser — Compression — Speed — Superheated Steam — Steam Jacket — Lagging — Governor — Gardner's Governor — Foundation — Steam Cylinders — Fly-Wheel — Stroke — Steam Chest — Area of Steam Ports — Piston Head — Piston Rod — Slides — Cross-Head — Connecting Rod — Crank Pin — Crank — Piston-Head Packing — Piston-Rod Packing — Care of Steam Engine — Pounding — Cylinder Lubrication — Indicator Diagrams and Expert Tests — Wheelock Engine — Computation of Horse-Power — Power and "Duty" — Cost of Putting in Steam Power — Cost of Fuel per Barrel of Flour.

Steam is a light elastic fluid, generated from the evaporation of any liquid by the application of heat, although the term is generally restricted to vapor of water, generated during a state of ebullition. The air which surrounds the earth presses upon its surface with an average weight equal to 14.7 pounds per square inch at the level of the ocean. This pressure is balanced by a column of mercury, 29.9212 inches in height. At higher altitudes this pressure is, of course, less, by reason of the lesser height of the air column. Under 14.7 pounds absolute pressure per square inch, fresh water boils at a temperature or sensible heat which marks 212° F. on the thermometer. To raise water from the freezing to the boiling point takes a certain time and a certain amount of fuel, and the application of more heat after the boiling has commenced produces gradual evaporation, taking more time and fuel to change it all into steam than to raise it from the freezing to the boiling point. This extra heat is absorbed by the water, and retained by it as long as it remains steam. The thermometer does not show it, so it is called latent heat. When the steam becomes again condensed into water, all of this latent heat is given back and becomes again sensible. If water is used to condense steam, the condensing water becomes hot, that is, shows sensible heat by absorbing the latent heat of the steam. Neither the sensible heat nor the latent heat, nor their sum, remain constant, but vary with the pressure. The table from Regnault, which will be found on the following page, gives the degrees of heat contained in saturated steam, in Fahrenheit degrees of heat and in English inches.

Mechanical Effect.—Take a cylinder of one square inch in area of cross section, fitted with a steam-tight, easy fitting piston. Put one cubic inch of water in the bottom of this cylinder and apply heat below. When the temperature of the water gets to be 212° F., it will boil, the piston will rise gradually, and if the cylinder is long enough it will rise to the height of 1641.5 inches, showing that the steam took up 1641.5 times the volume of the water from which it was generated. Thus the evaporation of one cubic inch of water will raise 14.7 pounds 1640.5 inches or 136.7 feet high, or do $14.7 \times 136.7 = 2009.49$ foot pounds of work. We are supposing

that there is no friction to overcome, and that the piston has no weight. Allowing the steam to condense in the tube, the atmospheric pressure will force back the piston to its original position on the top of the cubic inch of water, and the work done by the steam may thereby be undone, or, additional equivalent work done.

Expansion.—"Working steam expansively" is letting it into the working cylinder and cutting it off before the piston has completed its stroke, making less than a cylinder full of steam, by its expansive force, do more work than the same weight of steam would do if allowed to follow a piston under full boiler pressure. Taking a model cylinder of a condensing engine, two units in length and one in cross-section, admitting steam into it and cutting the steam off when the piston has made only half a stroke, that is, a stroke of only a unit in length, we will have, as the work done during the first half-stroke, $1 \times 1 \times 1$, that is, piston area times pressure times distance equal to one, for the work performed during the time when the steam was under full pressure. During the second half-stroke, however, in which the steam is expanding from a high pressure to a low one, we have a work done equal to $1 \times 1 \times 0.69$, that is, area times distance times mean pressure. The total work throughout the stroke thus equals 1.69. If, instead of expanding against the piston during the second half-stroke, we had exhausted the steam, the total work performed would only have been one instead of 1.69, although the steam consumed would have been the same quantity, so, by cutting off at half stroke we get 0.69 more work out of the same steam. If we had used steam at full pressure during the whole of the stroke, we would have got two units of work, but we would have used two volumes of steam. So it must be understood that in using steam expansively we do not get more work out of a given cylinder than if we used steam at full pressure throughout

REGNAULT'S EXPERIMENTS.

DEGREES OF HEAT CONTAINED IN SATURATED STEAM, IN FAHRENHEIT DEGREES OF HEAT AND ENGLISH INCHES.

Temperature of the Saturated Steam (Vapor at the Point of Condensation).	Corresponding Elastic Force.		Total heat, latent heat, plus sensible heat above. ° Fahrenheit.	Temperature of the Saturated Steam (Vapor at the Point of Condensation).	Corresponding Elastic Force.		Total heat, latent heat, plus sensible heat above ° Fahrenheit.
	In Inches.	In Atmospheres.			In Inches.	In Atmospheres.	
° Fahr.				° Fahr.			
32	0.1811	0.006	1123.70	248	58.7116	1.962	1189.58
50	0.3606	0.012	1129.10	266	79.9321	2.671	1194.98
68	0.6846	0.023	1134.68	284	106.9930	3.576	1200.56
86	1.2421	0.042	1140.16	302	140.9930	4.712	1205.96
104	2.1618	0.072	1145.66	320	183.1342	6.120	1211.54
122	3.6212	0.121	1151.06	338	234.7105	7.844	1216 94
140	5.8578	0.196	1156.64	356	297.1013	9.929	1222.52
158	9.1767	0.306	1162.04	374	371.7590	12.425	1227.92
176	13.9621	0.466	1167.62	392	460.1943	15.380	1233.50
194	20.6869	0.691	1173.02	410	560.9673	18.848	1238.90
212	29.9212	1.000	1178.60	428	684.6584	22.882	1244.48
230	42.3374	1.415	1184.00	446	823.8723	27.535	1249.88

the whole stroke, but we get more work out of a given amount of steam, consequently more work with a given amount of fuel. Thus, by making our engines large enough to use steam expansively, we are able to use less fuel to do a given amount of work. This 69 per cent. gain does not represent the exact gain in fuel; what this is we will explain further on. The spaces occupied by steam are inversely as the pressures, thus, if steam at 60 lbs. abs., in a given volume, is allowed to expand into double the space, it will have thirty lbs. abs. pressure; if into three times the space, twenty lbs. abs. pressure; into four times the space, fifteen lbs. abs. pressure; into five times the space, twelve lbs. abs. pressure, and so on. We can approximately calculate the pressure in a given cylinder under any degree of expansion by supposing it to be divided into a number of equal parts, say eight, getting a pressure at each of these points and averaging it. Suppose that we cut off at half stroke, the pressure at each division mark during the half stroke would be one; at the fifth division, 4-5 or .8; at the sixth, 4-6 or .666; at the seventh, 4-7 or .5714; at the eighth, 4-8 or 0.5. At this point it will be seen that the steam occupies double the volume that it did before it was cut off, and has half the pressure. Now, if we add the four last pressures together, and divide by four, we will get the mean pressure during expansion, and the mean pressure during the whole of the stroke will be found by adding the eight pressures together and dividing by eight. The average pressure during the expansion will be .6345, and the average during the whole stroke, 0.8172. The following tables give the ratio of pressures to point of cut-off at any desired point.

ACTUAL EXPANSION RATES; RELATIVE ADMISSION PERIODS, PRESSURES AND PERFORMANCE, ALLOWING REGULAR EXPANSION, AND NO WIRE-DRAWING NOR THROTTLING.

Actual Expansion. Initial Volume=1.	Hyp. Log. of Actual Exp. Rate.	Period of Admission Allowing Clearance of 7 % of Stroke.	Average Total Pressure.	Total Initial Pressure.	Total Final Pressure.	Rates of Performance of Equal Weights of Steam.
1.0	.000	100.	1.000	1.000	1.000	1.000
1.1	.0953	90.3	.096	1.004	.909	1.096
1.18	.1698	83.3	.986	1.014	.847	1.164
1.23	.2070	80.0	.980	1.020	.813	1.206
1.3	.2624	75 3	.969	1.032	.769	1.261
1.39	.3293	70.0	.953	1.049	.719	1.325
1.45	.3716	66.8	.942	1.062	.690	1.365
1.54	.4317	62.5	.925	1.081	.649	1.425
1.6	.4700	59.9	.913	1.095	.625	1.461
1.88	.6314	50.0	.860	1.163	.532	1.616
2.28	.8241	40.0	.787	1.271	.439	1.793
2.4	.8725	37.6	.766	1.305	.417	1.837
2.65	.9745	33.3	.720	1.377	.377	1.925
2.9	1.065	29.9	.692	1.445	.345	2.006
3.35	1.209	25.0	.637	1.570	.298	2.129
4.	1.386	19.7	.567	1.764	.250	2.278
4.5	1.504	16.8	.526	1.901	.222	2.370
5.5	1.705	12.5	.457	2.188	.182	2.511
5.9	1.775	11.1	.432	2.315	.169	2.556
6.3	1.841	10.0	.413	2.421	.159	2.597

In using steam expansively, we must, of course, commence with a greater pressure than if we are using it full stroke, because we must obtain the same mean pressure. Taking, for example, an engine using a steam pressure of 60 lbs. abs. per square inch full stroke, how much must that pressure be increased to work the same engine with steam expanded twice and obtain

TABLE OF HYPERBOLIC LOGARITHMS.

No.	Hyperbolic Log.	No.	Hyperbolic Log.	No.	Hyperbolic Log.	No.	Hyperbolic Log.	No.	Hyperbolic Log.
1.05	.049	3.05	1.115	5.05	1.619	7.05	1.953	9.05	2.203
1.1	.095	3.1	1.131	5.1	1.629	7.1	1.960	9.1	2.208
1.15	.140	3.15	1.147	5.15	1.639	7.15	1.967	9.15	2.214
1.2	.182	3.2	1.163	5.2	1.649	7.2	1.974	9.2	2.219
1.25	.223	3.25	1.179	5.25	1.658	7.25	1.981	9.25	2.225
1.3	.262	3.3	1.194	5.3	1.668	7.3	1.988	9.3	2.230
1.35	.300	3.35	1.209	5.35	1.677	7.35	1.995	9.35	2.235
1.4	.336	3.4	1.224	5.4	1.686	7.4	2.001	9.4	2.241
1.45	.372	3.45	1.238	5.45	1.696	7.45	2.008	9 45	2.246
1.5	.405	3.5	1.253	5.5	1.705	7.5	2.015	9.5	2.251
1.55	.438	3.55	1.267	5.55	1.714	7.55	2.022	9.55	2.257
1.6	.470	3.6	1.281	5.6	1.723	7.6	2.028	9.6	2.262
1.65	.500	3.65	1.295	5.65	1.732	7.65	2.035	9.65	2.267
1.7	.531	3.7	1.308	5.7	1.740	7.7	2.041	9.7	2.272
1.75	.560	3.75	1.322	5.75	1.749	7.75	2.048	9.75	2.277
1.8	.588	3.8	1.335	5.8	1.758	7.8	2.054	9.8	2.282
1.85	.615	3.85	1.348	5.85	1.766	7.85	2.061	9.85	2.287
1.9	.642	3.9	1.361	5.9	1.775	7.9	2.067	9.9	2.293
1.95	.668	3.95	1.374	5.95	1.783	7.95	2.073	9.95	2.298
2.	.693	4.	1.386	6.	1.792	8.	2.079	10.	2.303
2.05	.718	4.05	1.399	6.05	1.800	8.05	2.086	15.	2.708
2.1	.742	4.1	1.411	6.1	1.808	8.1	2.092	20.	2.996
2.15	.765	4.15	1.423	6.15	1.816	8.15	2 098	25.	3.219
2.2	.788	4.2	1.435	6.2	1.824	8.2	2.104	30.	3.401
2.25	.811	4.25	1.447	6.25	1.833	8.25	2.110	35.	3.555
2.3	.833	4.3	1.459	6.3	1.841	8.3	2.116	40.	3.689
2.35	.854	4.35	1.470	6.35	1.848	8.35	2.122	45.	3.807
2.4	.875	4.4	1.482	6.4	1.856	8.4	2.128	50.	3.912
2.45	.896	4.45	1.493	6.45	1.864	8.45	2.134	55.	4.007
2.5	.916	4.5	1.504	6.5	1.872	8.5	2.140	60.	4.094
2.55	.936	4.55	1.515	6.55	1.879	8.55	2.146	65.	4.174
2.6	.956	4.6	1.526	6.6	1.887	8.6	2.152	70.	4.248
2.65	.975	4.65	1.537	6.65	1.895	8.65	2.158	75.	4.317
2.7	.993	4.7	1.548	6.7	1.902	8.7	2.163	80.	4.382
2.75	1.012	4.75	1.558	6.75	1.910	8.75	2.169	85.	4.443
2.8	1.032	4.8	1.569	6.8	1.917	8.8	2.175	90.	4.500
2.85	1.047	4.85	1.579	6.85	1.924	8.85	2.180	95.	4.554
2.9	1.065	4.9	1 589	6.9	1.931	8.9	2.186	100.	4.605
2.95	1.082	4.95	1.599	6.95	1.939	8.95	2.192	1,000.	6.908
3.	1.099	5.	1.609	7.	1.946	9.	2.197	10,000.	9.210

the same power? The mean pressure of steam expanded to double its volume is $84\frac{1}{2}$ per cent. of the initial pressure, and consequently $60 \div 0.845 = 71$ lbs. abs. per square inch, which is the steam pressure required. In the first case we used 60 lbs. abs. full stroke, and in the second 71 lbs. abs. half stroke, which makes an economy of $(60 - \frac{71}{2}) \div 60 = 0.41$ nearly, or

41 per cent. gain. In practice, about one-half of this saving is neutralized by various sources of loss connected with the boiler.

This does not mean 41 per cent. less fuel put in the furnace, but 41 per cent. of that which reaches the cylinders, lessened by a slight condensation due to expansion. There is, of course, a loss from part of the fuel not being combustible and part of it going out of the chimney in the shape of heat to produce draft, part lost by radiation, part lost by condensation in the pipes, &c., so that the actual saving in cutting off at half stroke is more nearly 20 per cent. than 41 per cent., and this should not be confounded with the 69 per cent. of theoretical increase of work done by the same weight of steam over what it would have done had it not been cut off.

When we say "quantity of steam" we always mean weight of steam, unless volume is distinctly stated.

We can represent the pressure which the steam has at any point in the cylinder very nicely by means of diagrams representing so many pounds to the inch. If there was a perfect vacuum in the cylinder there would be no limit to expansion, but there really is a limit. There should be enough unbalanced at the end of the stroke to overcome the friction of the engine. If there is three pounds back pressure above atmosphere and one and a half pounds friction, there must be at least six pounds pressure above atmosphere at the end. For non-condensing engines, the calculations are made the same way as for condensing, always remembering to add to the initial pressure, shown on the gauge, which is pressure above atmosphere, 14.7 lbs. for calculation based on performance at the sea-level. In higher districts, the atmospheric pressure is less—say 14.5 lbs. in Ohio. The ordinary main valve of an engine should not cut off with lap and lead earlier than at $\frac{3}{4}$ of the stroke, making $\frac{1}{4}$ stroke expansion or 1.33 nominal expansion rate; and even then, the valve and valve gear must be carefully regulated, so that the exhaust will not open and close too soon. The main valve is sometimes made to cut off earlier, but it does not regulate the steam economically.

Throttling and Wire Drawing.—When the steam used in the cylinder has its free access retarded by passage through a throttle valve, partly closed, it is said to be throttled. When steam is cut off very slowly by an ordinary slide valve, it is simply retarded, but the effect is called wire drawing. When a single eccentric is used, the earlier the cut off, the more the wire drawing. Wire drawing may be lessened by double eccentrics and slide, gridirons and so on. It is best avoided by the Corliss type of gear, by which the steam valves are opened and closed suddenly by springs. Throttling and wire drawing are accompanied by direct loss, due to the slight friction which takes place during the process, and by indirect waste by reason of the increased proportion of work expended in overcoming back pressure.

Wire-drawing is advantageous under some circumstances and disadvantageous under others. Steam is heated by wire-drawing, and moisture

in it is thus, to a certain extent, evaporated. When the steam is cut off at half stroke, or earlier, it is advantageous to wire-draw it through the slide valves or throttle valve, because it will then expand livelier and leave no water of condensation in the cylinder. But when the steam is admitted full stroke there is disadvantage in wire-drawing, because the steam will then leak, as it were, into the cylinder to nearly the full boiler-pressure at the end of the stroke, depending upon how fast the engine runs; and thus much steam will pass through without doing full work.

Back Pressure.—It is impossible in practice to get a perfect vacuum, or even a perfect outlet for the steam at the return stroke, consequently there is always a certain amount of steam in the cylinder opposed to the motion of the piston, causing what is called "back pressure." If we have an average pressure of 20 lbs. by gauge driving the piston forward, and a pressure of 4 pounds retarding the same, the mean effective pressure would be but 16 pounds, and that four pounds must be deducted from the working pressure in order to give the unbalanced pressure at the end of the stroke.

Economy of High-Pressures.—The measure of the deficiency of a steam engine is the steam rejected, that is, the terminal pressure. The measure of the economy is the mean effective pressure less the average back pressure. Having a constant pressure to throw away, we want to get all out of it that we can. If we start with ten gauge pounds, = 24.7 lbs. absolute, and by cutting off at about one-sixth, expand to 5.3 gauge pounds terminal pressure = 20 lbs. above vacuum, we get a quantity of work equal to the band A, Fig. 66, or 9.3 pounds mean effective pressure.

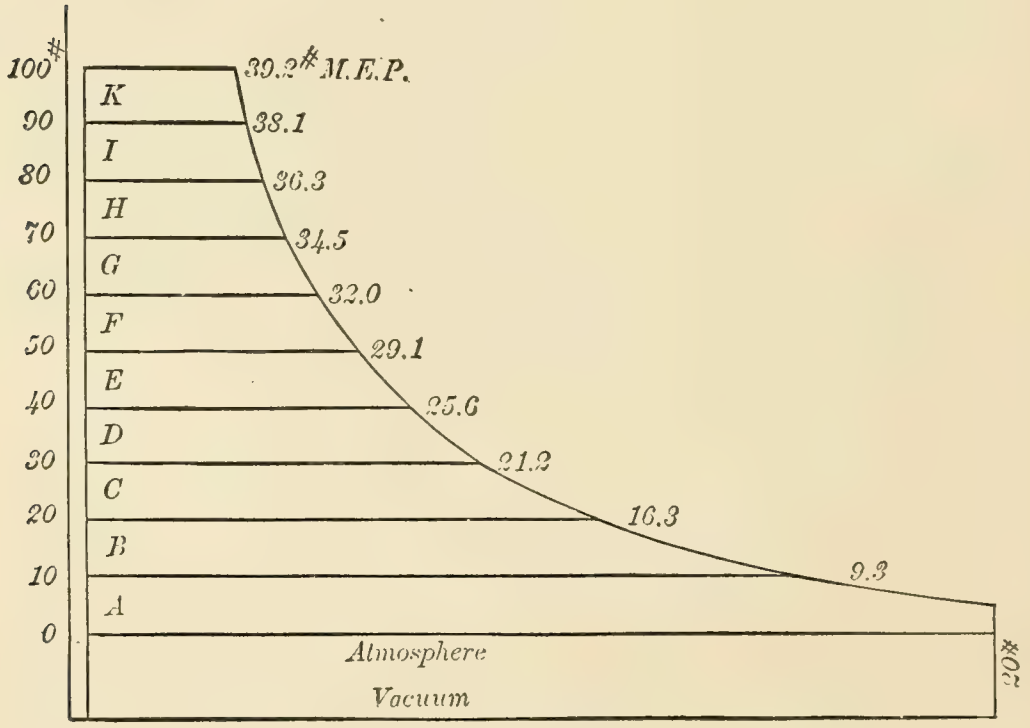


Fig. 66.—Scale for High-Pressure Steam Engine.

If we start with twenty gauge lbs. initial pressure, we get more work (which is represented by the band B) for nothing, raising the mean effective pressure to 16.3 pounds, or 76 per cent. gain at present. 100 gauge lbs. initial pressure is about the limit of present good and politic practice. The following table gives the water consumption, economy of fuel and gain of power :

Initial Pressures.	M. E. P.	Lbs. Water per hour per H. P.	Gain of Power per increment of 10 lbs.	Economy of Fuel per increment of 10 lbs.
10 gauge lbs. .	9.3	75.3	Per Cent.	Per Cent.
20 " " . .	16.3	42.9	76	43
30 " " . .	21.2	33.0	30	23
40 " " . .	25.6	27.3	20	17
50 " " . .	29.1	24.0	14	12
60 " " . .	32.0	21.9	10	09
70 " " . .	34.5	20.3	08	07
80 " " . .	36.3	19.2	06	05
90 " " . .	38.1	18.4	05	04
100 " " . .	39.2	17.8	03	03

Condenser.—There is a difference between absolute pressure and the ordinary nominal pressure which is indicated by pounds per square inch above that of the atmosphere. Water evaporated in the open air is at zero pressure instead of steam at 14.7 pounds per square inch, counterbalancing the atmospheric pressure. Such steam used in a condensing engine is said to be working "*in vacuo.*" To distinguish the steam pressure above vacuum from that above atmospheric pressure, European engineers adopt the distinction "*over pressure*" and "*under pressure.*" When steam of higher pressure is used, it is usual in calculating the horse-power to add the so-called vacuum to the so-called steam pressure. Now, to use a condenser is simply to remove an opposing force. The condenser is not a power generator. It simply enables all the work done by the steam in the cylinder to be brought to bear upon the piston instead of some of it being wasted in pushing away atmospheric pressure. This does not mean that there is air on the other side of the piston, but that the steam on the exhaust side of the piston is pressed against the piston by the atmospheric pressure from without. In the condensing engine, this atmospheric pressure is almost entirely removed. The only force to oppose the steam pressure on the working side of the piston is the strain in the rod plus a pound or two of so-called "back pressure" in the condenser. If the condenser gave a perfect vacuum there would be none of this so-called back pressure ; but then there would be no pressure in the condenser to press out the condensing water through the foot valve of the pump. The simplest form of condenser is the "syphon condenser" of which there are several styles.

Compression.—Excessive compression of steam at the end of the exhaust stroke, is not advantageous, because it makes a back pressure on the crank pin before reaching the centre. It has been argued that the compression, generally called "cushioning," is advantageous by reason of fitting the clearance and causing a ready pressure for the near stroke ; but that advantage does not by far compensate for the back pressure on the crank

pin. In very fast running engines it has been found by experience that strong cushioning is necessary to make them run smooth, but a little more lead of the main valve will answer the same purpose and better utilize the effect of the steam.

Clearance has the advantage that it leaves a safety space between the piston head for preventing the piston from striking. The disadvantage of clearance is that the steam volume inclosed therein is lost for the effect of the engine when no expansion is used. But when the steam is expanded in the cylinder the clearance steam is also expanded and is thus partly utilized for work. The higher the expansion used, the more will the clearance steam be utilized.

"Cut off at," means from the beginning of the stroke. The proportion of power utilized by the clearance steam, which may also include that in the steam port, is as follows:

Steam cut off at	$\frac{3}{4}$,	$\frac{5}{8}$,	$\frac{1}{2}$,	$\frac{3}{8}$,	$\frac{1}{4}$,
Per cent utilized,	46,	58,	69,	78,	95.

Speed.—The tendency is to use short stroke and high speed of revolution. Thus, instead of a 16 × 48 engine using 80 gauge lbs. of steam cut-off at one-quarter stroke, and making 60 revolutions, we can get the same power out of a 13 × 24 engine with the same pressure and point of cut-off, but running 200 strokes per minute. The 13 × 24 engine costs much less than the 16 × 48, and does the same work with the same fuel, but its life must be somewhat less by reason of the greater number of shocks of reversing at each end of the stroke.

Superheated Steam.—Steam as first generated in a boiler contains a certain amount of water, or, in other words, is not dry.

On being brought in contact with the heating surfaces this saturated steam will absorb heat from them, and thus the water in the steam will be evaporated, the steam becoming what is called dry. Dry steam is no hotter than saturated. After it becomes dry it may still absorb heat, and there being no more work for this extra heat to do in evaporating water, the steam becomes hotter, or superheated. Wet steam does not work economically in the engine; dry steam is much more economical, and superheated steam is more economical than either. This economy has been calculated by Rankine and others. In an engine taking steam at thirty-four (34) pounds pressure above the atmosphere and expanding it to five times its original volume (in other words, cutting off at once one-fifth stroke) there will be an economy of 15 per cent. by superheating steam from its former temperature of 257° to 428°. If this superheating could be done by heat which would otherwise be wasted, instead of by heat, some of which might have been used in making saturated steam, the economy would be 23 per cent.

Steam Jacket.—The steam jacket has, for its effect, to prevent condensation in the cylinder by furnishing heat to the expanding steam. Wet steam is a rapid absorber of heat, and dry steam a slow one. On cylinders of great diameter and of very quick stroke the effect of the jacket cannot reach the middle of the cylinder quickly enough to prevent condensation. The result of the jacket is to get work from steam, which does not enter the

cylinder, by condensing in the jacket instead of in the cylinder. Still the same amount of steam is condensed outside as there would be inside, perhaps a little more, because the film is thinner than the circumference of the jacket is larger than that of the cylinder. But very often we find that the jacket does not result in any economy of steam consumption, but increases the power of a small engine without changing the initial pressure or the rate of expansion. The steam jacket was at first applied around the body of the cylinder only, then to the end and cover, and some engineers have admitted steam to the piston. The larger the surfaces, the greater the advantages of a jacket. In speaking of jackets we always refer to the steam jackets and not to hot air jackets.

Lagging.—Every steam cylinder should be lagged with wood, asbestos, mineral wool, felt, or other non-conductor of heat, to prevent radiation of heat and condensation in the cylinder.

Governor.—The centrifugal governor is of advantage in securing economy of fuel and approximate regularity of motion, but there are some peculiar defects which are insurmountable. Put in very plain English, in order for a centrifugal governor to work, the engine must *go fast in order to go slow*, or must go slow in order to go fast, since there cannot be a change of height of the balls without change of speed in the engine and balls. Again, the opening of the steam valve depends upon the angle between the arms of the balls and the central spindle around which they revolve. So, if we have an engine doing its full amount of work, the governor will keep at a uniform speed so long as the average resistance of the engine stays the same; but, as soon as any work is taken off, the engine's speed will be increased by reason of the lessening of the work, and the engine will run uniformly enough at this higher speed so long as the work remains without further alteration, as the degree of opening the steam valve is determined by the angle to which the governor arms are raised by the velocity of the revolution.

The steam valve can be moved only by a change of speed of the governor balls and a consequent change of their angle of suspension, hence a larger supply of steam to do the increase of work can be got only in conjunction with a smaller angle of the governor arms; and, secondly, with a slower speed, and in order to partly shut off steam to meet a reduction of work, the balls must have a higher speed in order to lift them to a greater angle. In order to make the governor sensitive it must have a high speed. The higher its speed in comparison with that of the engine, the more sensitive it is, because by this means whatever variation of speed there is in the engine is multiplied many times in the governor. However, the higher speed you get the more wear you get, and with wear comes lost motion, which is liable to cause trouble to the engineer and sudden variation in the speed of the engine. Another trouble is that the governor must have strength enough to do a certain amount of actual work holding and moving the valve, and it must work evenly and surely, no matter whether the valve stem in its stuffing box or the valve itself sticks. This power can be got either by a very high speed with its attendant wear, or by very heavy balls, which

make the device large, cumbersome and expensive. If the fly wheel is properly proportioned, there is less need of a sensitive governor than if it is made from a pattern on hand made for some other engine of entirely different proportions, and working under entirely different conditions. In the Corliss engine the governor does not do any work, but simply shows where the cut-off is to be effected, and if the fly wheel is of proper weight and size it is attended with great regularity of speed and economy of fuel.

A writer speaking of steam engine governor tests, says: "We are unaware of any reliable tests having been instituted as to the sensitiveness and correct working of steam engine governors, and still it would seem that this was desirable, especially to judge of the efficiency of new forms of governors. The subjoined brief outline of the kind of test necessary will, therefore, not be without interest. The object of a governor is to act on the throttle valve or cut-off mechanism in such a manner that when the load is increased more steam will be furnished to the engine, and when the load is diminished the supply of steam will be decreased to a corresponding extent, so that whatever the work to be done by the engine within certain limits, the number of revolutions are to remain practically uniform. To test whether this action takes place with a given governor, it becomes necessary to make two series of experiments, attaching the governor to the throttle valve and cut-off mechanism respectively. The engine, after noting the working of the governor, should be released from the greater portion of its work suddenly, and the length of time and number of revolutions occupied by the engine in recovering itself noted. Indicator cards should be taken before the work is thrown off, and after the engine recovers itself, thus enabling the amount of work thrown off to be determined. The work is then again applied, and the reverse effect observed and recorded. Complete tests should comprise a variation of steam pressures, loads and other conditions, as well as dynamometrical measurement of the actual power developed."

It not infrequently occurs after an ordinary throttling engine has been used a few years, that the speed becomes variable to such a degree that it interferes with the proper running of the machinery. This occurrence can generally be traced directly to the governor. When it does occur, the governor should be taken apart and thoroughly examined; if the needed repairs are such as can easily be made in an ordinary repair shop, they should be made at once, if not, a new governor should be purchased. The price of governors is now so low that it is better and more economical to buy a new one than lose the time and pay the bills for repairing an old one. The governor made by R. W. Gardner, of Quincy, Ill., (Fig. 67) may be recommended.

Gardner's Governor.—This governor is made with or without an automatic stop. In Fig. 67, it is represented in its automatic form. The valve is novel in construction and method of balancing, and consists of two discs connected by guide bars. By the peculiar method of receiving and delivering the steam, the valve is passive under varying pressures, and is affected by the current action of the steam.

A committee of the Franklin Institute made tests of Gardner's Governor

in 1877 or 1878. Brief extracts from these tests are given below. The ordinary pendulum governor must run faster or slower to admit less or more steam, hence the engine must run faster or slower for that purpose. This is because a higher position or greater divergence of its balls demand a higher speed, and *vice versa*. But it is desirable that engine and governor should run at a uniform speed, and that the changing demand upon the engine for work be met by a change in the point of cut-off, in the case of an automatic cut-off engine, or in the amount of steam admitted, in a throttling engine.

There is no governor of which we know which is perfectly isochronous (or even speeded); but in the Gardner Governor this quality exists in a high degree, as shown by the tests made at the Franklin Institute in 1877. The pendulum balls are hung to a toggle joint in such manner that a rise of the balls, due to an increase of engine speed, tends to flatten the toggle out laterally, and a decrease in speed, or dropping of the balls downward and inward, tends to open the toggle laterally. Attached to a horizontal lever is an adjustable weight which tends to flatten the toggle out horizontally.

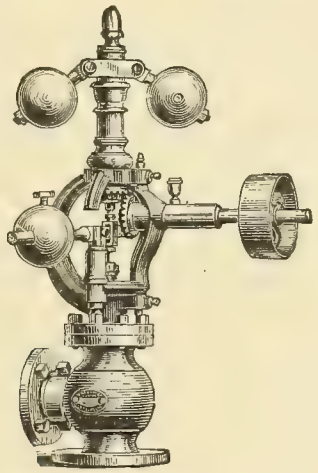


FIG. 67.—GARDNER GOVERNOR.

The governor is regulated by setting the weight on the horizontal lever, farther in or out (or by increasing or diminishing it), and by a screw at the top acting on the toggle.

At the Franklin Institute experiments, with the ball $8\frac{1}{2}$ inches from the centre and the toggle screw full up, the maximum revolutions was 216 and the minimum 192, the regulation being to 11.8 per cent. With toggle screwed down $\frac{3}{16}$ inch, and weight the same as in the first experiment, the regulator was to 12.54 per cent. With the weight $6\frac{3}{4}$ inches from the centre, and toggle left $\frac{3}{16}$ inch down, the regulation was within 6.9 per cent. With weight 5 inches from centre, and toggle allowed full action, regulation was to within 14.55 per cent. of isochronism.

No steam engine should be without an "automatic stop motion," by which the governor shuts off steam entirely, and at once, in case of breakage of main belt, or similar accident, which would otherwise cause damage by permitting the unloaded engine to "run away."

Foundation.—The foundation should be solid, massive, well laid in

cement, and accurately level, otherwise there is wear and loss by reason of vibration and settling. If either main bearing sinks, the shaft will be strained and the main journal and brasses heat and wear. Foundations should be of brick or cut stone, upon a solid concrete bed. The bolts should be stout and run well down through.

The bed-plate should be leveled up with sulphur, lead, or Portland cement.

Steam Cylinders.—Cast iron is the metal generally employed for steam cylinders. The hardest iron that it is possible to work should be used for this purpose. Steel bushes have been used, and have well repaid in durability the extra cost. In order to make the bore perfectly true, large cylinders should be bored in the position they are to occupy when they are in use. The cylinder should be sufficiently thick to provide for boring and reboring, and to give perfect stiffness of position and form. With some forms of cut-off the admission of steam to the cylinder partakes of the nature of an explosion, hence the cylinder needs to be extra strong. The thickness should increase with the boiler pressure and with the diameter. The cylinder should be thick enough to stand the required steam pressure and to allow for reboring two or three times. The heads may be strengthened by external ribs. For average practice the heads may be $1\frac{1}{4}$ times the thickness of the walls. Thoroughfare bolts are better than studs fitting rust-tight and breaking off. Bolts should be close together to prevent leakage. The number of bolts or their area should be determined by the boiler pressure and cylinder diameter.

Care should be taken to get an engine of the proper size and kind for the kinds of work to be done. In any case, it is best to have high initial steam pressure and high grade of expansion. This is simply as a matter of economy. The passage from the ports to the cylinder should be as straight and smooth as possible. To get a cylinder with the least surface compared with its volume, the diameter of the cylinder must be equal to its length. For this reason, the best relative proportions between piston stroke and diameter are obtained when they are equal. Then use of short cylinders has the advantage of reducing the piston speed, and, consequently, the wear on the piston packing for any given number of revolutions, although the steam cylinder wears the same for any given number of strokes per minute.

Fly-Wheel.—The fly-wheel will not control the speed of the engine for any length of time, nor will it render the motion of any engine exactly uniform for even a short period of time ; but, if it is properly proportioned in weight, diameter and speed, to the power exerted by the steam cylinder, it will confine the variation of the engine during any one stroke within reasonable limits. The function of the wheel being to store up work to be given out when required, the larger it is and the higher its speed, the more steadily it runs, and only for high cost and increase of friction, it would be impossible to make a fly-wheel too large. The more irregular the work the heavier the fly-wheel should be. If there is any one point where the motion is particularly variable, the conditions may be improved by introducing a fly-wheel at this point. The fly-wheel generally has a diameter from three to ten times the length of the stroke. Of course, the same amount of work

can be got out of a lighter weight of metal if the rim is made large enough. The weight and cost of a fly-wheel may be diminished by increasing the number of strokes or the diameter of the wheel. Watt's rule is to make the work stored in the fly-wheel equal to the work of the engine during seven and a half strokes. Bourne's rule makes the work stored in the fly-wheel equal to that developed by the steam cylinder in six strokes. There are some machines which will permit of more uneven motions than others, as for hammer work. Pumps and shearing machines will permit rather less irregularity. Flour mills require an approximation to a uniform speed. Weaving machines and paper mills require still greater uniformity. Cotton spinning machines must have a very uniform speed, and spinning machinery for very high yarn numbers is the most exacting of all.

The centre of gravity of a fly-wheel must coincide with the centre of the shaft on which it is placed. A fly-wheel may be circular and yet have its centre of gravity outside that of the shaft. It may be out of circle and yet have its centre of gravity coincide perfectly with that of the shaft. In this latter case it might serve excellently well as a regulator, but would not do as a pulley fly-wheel, because if one of its diameters was longer than another it would impart uneven motion to all smaller wheels driven from it, and the smaller these wheels the greater the disproportion would be. There is a certain limit beyond which the rim of a fly-wheel cannot be speeded, because there is a certain point at which there is danger of bursting the rim by centrifugal force. Eighty feet per second rim speed should not be exceeded.

Stroke.—When the stroke and cylinder diameter are equal there is less surface for condensation, less piston speed for a given rotation speed than where the stroke is longer, and less wear on the packing; although for a given number of rotations, the cylinder wear is the same for any given number of strokes per minute.

Steam Chest.—The steam chest, where there is one, should be as small as possible to lessen loss by condensation. The thickness of steam chest is determined by reference to the breadth and longest inside measurement, the boiler pressure and the tensile strength of the iron forming it.

Area of Steam Ports.—The area of steam ports is governed by the piston speed. The greater the piston speed the greater the required port area. For 600 feet per minute piston speed, the port area may be $\frac{1}{10}$ the piston area, and in this proportion for other piston speeds.

Piston Head.—Horizontal cylinders take broader and thicker piston heads than vertical cylinders do, and the higher the speed and rougher the usage, the greater the piston thickness needed. The thickness also should vary with the diameter of the cylinder.

Piston Rod.—The piston rod should be of steel, as giving with the same diameter greater smoothness and stiffness than a wrought-iron rod, or for the same stiffness less weight and less reduction in the area of the crank side of the piston, which is always less than the other side. The rod must stand the alternate pull of the heaviest work and not bend in the slightest degree, else the packing will be destroyed and work lost.

Slides.—When an engine throws over while the piston head moves

toward the main shaft, all of the pressure and wear come upon the lower side; and *vice versa*. It is best that the engine should throw over, as lubricants spread over the lower guide better than on the upper, and because overthrowing tends to press the guides down to the beds rather than to uproot them.

Cross Head.—The cross head is generally laid down by rule of thumb. When an engine throws over all the wear and pressure come upon the under slide and when it throws under the upper guide gets it. Cross heads having only one guide would answer only for engines running in one direction. For purposes of lubrication it is better to have the engine throw over; and this also enables the guide to be made stiffer. Where guides are fastened all along their length to the frame they may be of cast iron, but under other circumstances they should be of wrought iron or steel, which are more rigid.

Connecting Rod.—The connecting rod is generally two or four times the stroke. The connecting rod diameter should increase with the boiler pressure and steam cylinder diameter. A steel connecting rod may be from one to one and a half times the diameter of an iron piston rod.

Crank Pin.—The crank pin must be strong enough not to break, and also of such proportion as not to heat; the latter being the most difficult thing to accomplish. The less the diameter the easier oils are expelled. Brass boxes conduct heat two to four times quicker than cast iron ones. Where the pressure exceeds 195 pounds per square inch of projected area, the boxes had better be of brass or soft metal, because if the film of lubricant breaks the metal will go, while with cast-iron boxes heating commences and cannot well be stopped. Increase in speed increases the crank pin friction more than increase of pressure does. This is because the lubricant is expelled more rapidly. The length of the crank pin should increase with the coefficient of friction, the boiler pressure, the number of revolutions per minute and the diameter of the connecting rod.

Within reasonable limits, the longer the crank pin the cooler it will work, its diameter having little effect upon the heating, because if the diameter is increased the pressure per square inch is lessened in just the proportion that the velocity of the rubbing surface is increased.

The crank pin is a beam fixed at one end and loaded uniformally through its length, but sometimes by reason of deflection it is more like a beam fixed at one end and loaded at the other.

The length of steel and wrought-iron crank pins is the same, and the thickness may be the same also. Steel makes the best crank pin by reason of its greater strength and better surface; though steel pins have the disadvantage that they are liable to snap when not working truly. Where the initial and the final pressures upon the crank pins are equal the reciprocating parts should be as light as possible. Where an engine cuts off at half stroke the pressure is greatest at mid-stroke.

Crank.—The crank should be of wrought iron or steel. Cast cranks will not admit of the pin being shrunk in the eye without danger of cracking. High heat in shrinking is apt to warp a forged crank. It is, perhaps, better to give a little taper to the pin and use hydraulic pressure to force it in.

The tapering faces of the crank ought really to be a parabola having its base in the centre of the shaft and its vertex in the centre of the crank pin. The nearest outline to this would be its tangents.

The use of two or more keys is attended with great economy of material in the keys and lessens reduction of cross section of the shaft, while the safety is equally great.

Piston-Head Packing.—A packing ring larger than the cylinder will never fit the cylinder when cut to pieces. The safe side of a piston fit is the small side. Even those rings which are intended to spring out of their own accord and fill the cylinder, should be turned to fit, and after they are cut they may be opened out by pening or by expanding them on a lathe chuck. An engine should not be packed tight in any part. If it cannot be kept in good order without squeezing the packing down hard, it must be in poor condition. A cylinder that is scratched, or is worn to a shoulder on the ends, can never be made tight.

Piston-Rod Packing.—The packing of the piston rod and valve rod is very frequently out of order. The causes of this are too high speed, want of alignment, leaky piston, bad piston rod, too high steam pressure, too little cylinder clearance, character of the packing, manner of applying it, and kind of treatment it gets. If the engine is out of line the piston will crowd the packing to one side at certain points of the stroke. If the rod is badly fluted the steam will escape through the grooves. If the piston leaks there will be too much cushion, which will cause the packing to leak. If there is too little clearance between the follower and the cylinder head, the steam will escape through the stuffing box. If the packing rings are cut too long they will not hug the rod; if made too short they will not meet, and in either case there will be leakage. If the material is not the proper size of the box, no amount of screwing up will make it a tight job. If the gland is screwed up too tight at first, the packing will be destroyed, as will be the case with too high engine speed. High pressure, with its attendant high speed, ruins most packing. Few engines have deep enough stuffing boxes; there should be enough room for four rings at least. For packing purposes there are a great many materials, such as soapstone, paper, india-rubber, asbestos, tin-foil, webbing, wire cloth, metal rings, etc. To properly pack the box, put just as much packing in it as will barely allow the gland to enter, screw it up solid and put it in place, then slack it up to allow for expansion when heated. If there is too much leakage, stop the engine, take out the gland, remove a few pieces of packing and replace them in another position which may stop the leak. Never set the packing, when taken out, on the floor, or in any place where dirt or grit may adhere to it; keep it tightly wrapped up. Never use rough instruments to remove the packing, as you may scratch the rods. To find the diameter of packing for any stuffing box, measure the diameters of the rod and of the gland, and half their difference will be their proper size. One of the best metal packings is that made by L. Katzenstein, of New York. It consists of coned split rings of anti-friction metal, which surround the rod and make it smooth and burnished (Fig. 68). The metal composition employed for this packing adheres to the rod, and at the same time is soft

enough not to affect it. The construction is composed of conical plates and different rings, those again composed of two parts. The exterior cone presses the interior against the wall of the stuffing box, and even under great pressure it remains locked. As each ring is a valve seat in itself, and each is divided into two parts, the whole is elastic and works easily. In this series of half rings (each section being composed of four pieces)

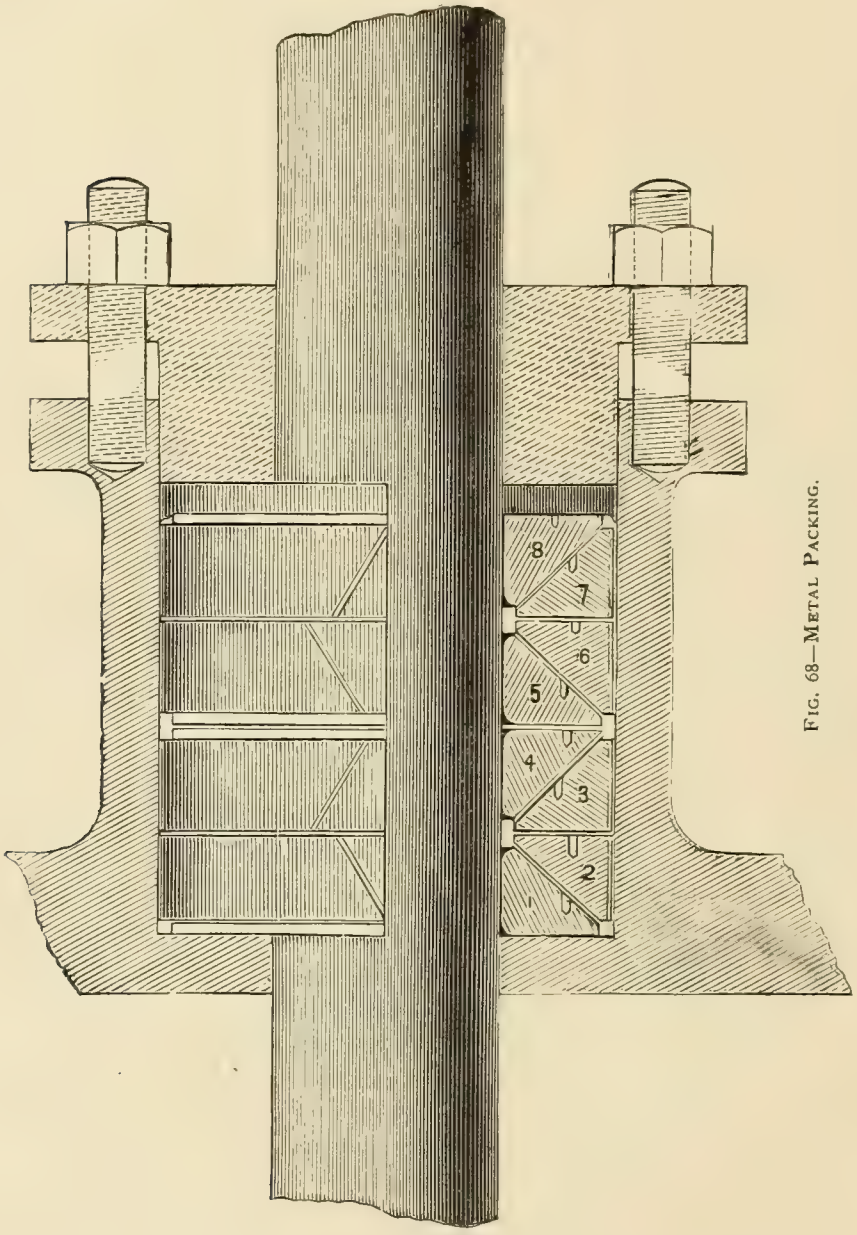


FIG. 68—METAL PACKING.

the corresponding pieces in all the sections are exactly alike, so that any piece broken, injured or worn can be easily replaced. These sections, also, are so placed as to have intermediate annular recesses, within which the water of condensation may be collected, and which, moreover, will permit the entire packing to be taken apart for purposes of inspection, or reset from time to time in case of wear. Next to the gland a gasket of soft packing is laid, capping the metal packing and enhancing the elas-

ticity. The advantages claimed for this metal packing are the following: It gives a perfectly tight stuffing box, likewise a steadying to the rods and stems, with little or no friction; it keeps the rods and stems perfectly smooth, and requires little lubrication; it will not corrode the rod when the engine is not in use.

The rubber-core coil packing, made by the New York Belting and Packing Company, is largely used and gives good satisfaction.

In about two engines in three, if we glance in the neighborhood of the stuffing box, we shall see one or more jets of steam issuing from around the rod during the whole or during a portion of every out-board stroke, or if we do not see this we will find the rod to be packed down so hard that it is gradually becoming worn or fluted. The piston-rod packing must let the rod move freely in every direction, with little friction, and without allowing the steam to escape. It must also be durable. With hemp or tow packing the rod becomes dull and appears scratchy as though draw-filed with a cross file. This is by reason of the grit which the fibres contain. Then the scratched rod cuts the packing. This is more likely to be the case if the rod is out of centre, varies in diameter, is crooked or out of round. Piston rods wear smallest in the middle, and oval at the ends, the lower end of the rod being worn most upon the bottom, while the crank end will be most worn on the top. Very often the rod and piston are purposely set a little high at first.

Care of a Steam Engine.—Whenever it is necessary to make repairs, the work should be done at once. Oftentimes a single day's delay will increase the extent and cost four-fold. If an engine is properly designed and built, the repairs required ought to be very trivial for the first few years it is run, if it has had proper care. It may be said in reply to this, "True, but accidents will happen in spite of every care and precaution." That accidents do occur is true enough, that they occur in spite of every care and precaution is not true. In almost every case accidents may be traced directly back to either a want of care, negligence or to a mistake. Eccentric straps are likely to need repairs as soon as anything about an engine. They should be carefully watched at all times. If they are likely to run hot, it is also probable that there is more or less abrasion or cutting going on. If so, and prompt measures are not taken to arrest it, they are likely to cut fast to the eccentric and a breakage is sure to occur. When the straps begin to heat, the bolts should be slackened a little, and at night, or perhaps at noon, the straps should be taken off and all cuttings carefully removed with a scraper (not with a file), the rough surfaces on the eccentric being removed in the same manner. The straps should be run loose for a few days, gradually tightening as a good wearing surface is obtained. The main bearing, if neglected, is a very troublesome journal to keep in order. The repairs generally needed are those which attend overheating and cutting. The shaft, whenever possible, should be lifted out of the bearing, and both the shaft, bottom of main bearing and side boxes carefully scraped and made perfectly smooth. It sometimes occurs that small beads of metal project above the surface of the shaft, which are often so hard that neither a scraper nor file will remove them, Chipping is then resorted to, and the fitting completed with a file and fine

emery cloth. In the care and management of automatic engines it is difficult to say just what particular attention they need, owing to the variety of styles and the peculiarities of each. As a rule, however, they require, first, to be kept well oiled ; second, to be kept clean ; third, to be kept well packed ; and, fourth, to be let alone nights and Sundays. There is little doubt that there has been more direct loss resulting from a ceaseless tinkering with an engine than results from the legitimate wear and tear to which the engine is subjected. The writer does not wish to be understood as saying that builders of this class of engines are infallible ; it might be difficult to prove any such assertion in case it was made, but it may be said, with truth, that the engines of this class now in the market are carefully designed, well proportioned, of good materials and workmanship, and, as examples of mechanism, are entitled to take very high rank. A manufacturer writes thus, to the builder of his engine : "The engine which you furnished us (16 × 30) has been in constant use for more than four years, running at 132 revolutions per minute, sometimes as auxiliary to water-power and sometimes at its full power. It has cost us nothing for repairs." It is essential to the economical working of these engines that the cut-off mechanism be in good order and properly adjusted. Whenever the valves need resetting the final adjustments should be made with a load on the engine, and with the indicator attached to the cylinder, the valves being set by the card rather than by the eye. No general rule can be given for setting the valves, as the practice varies with the size and speed of the engine, nor is any rule needed, for the indicator will furnish all the data required. The adjustments may then be made so as to secure prompt admission, sharp cut-off, prompt release and the proper compression.

The practice of fitting a slide valve to its seat by grinding both together with oil and emery is wrong, and should never be resorted to. The proper way to fit the surfaces is by scraping; this insures a more accurate bearing to begin with, and will also be entirely free from the fine grains of emery which find their way and become imbedded in the pores of the casting, and are thus liable to cut the valve face and destroy its accuracy. The scraping of the valve and seat has a beneficial effect by causing the removal of the fine particles of iron which are loosened by the action of the cutting tool in the planing machine, and which ought to be fully removed before the engine leaves the manufacturer's hands. Aside from this, it is doubtful whether the scraping amounts to anything practically, for the reason that the cylinder and valve are fitted cold and their relative positions are distorted by the action of the heat of the steam, once the engine is in use. The scraping, which simply renders the valve face and seat smooth and hard, is all that is sufficient to begin with, and may be rescraped after the valve has been in use a few days, should it be found necessary, which will not often be the case in small and ordinary sized engines.

Although large slide valves are still used in marine engines, it is only because no equally efficient substitute has been brought out. They do not work satisfactorily for any length of time, especially at high speed. The slide valve cannot cut off at less than half stroke very well without interfering

with the exhaust. The horizontal engine has the advantage of being compact, easily held to its foundation and accessible. To illustrate the difference between a large engine at slow speed and a small one at high speed, a 16 × 48 inch engine, using eighty pounds of steam, cutting off at one-fourth and running at sixty revolutions, may be replaced by an engine of the same pressure and same cut-off, having a 13 × 24 cylinder and running at 200. For small powers and small investments the engine had best have a common slide valve if the cylinder is eight inches or less in diameter. From eight to fourteen inches diameter the automatic slide cut-off answers well, as being low-priced, economical and efficient, running at a quick speed and giving as good results as a large and more costly slow running machine. In most engines there is more trouble with the crank pin than with all other parts. The crank pin is very liable to get hot, and is very troublesome when it does get so. There are several reasons for this heating, among which may be mentioned that the main shaft is not square with the engine, the pin not properly fitted to the crank, and too small, or the boxes too tightly keyed or not well enough oiled. The old style of oil cup is very poorly adapted to crank pin lubrication, and should be superseded by some of the new inventions for this purpose, which are automatic, effectual and certain in their action.

Pounding.—Lack of alignment causes knocking and pounding. With the Corliss type of frame, if the engine is properly aligned at first, it will not be likely to get out of line except that the wear of the crank shaft bearing will cause the shaft to drop. The crank centre line must stand true with the axle line of the cylinder when the crank is on the dead centre. If the engine has a flat bed and adjustable guides, any error in the planing of the cylinder flange is magnified five times at the pall block, hence the cylinder must be so lined that the line through its axis will pass through the pillow block at the centre of the bore of its brass. It must not be expected that a new engine will always start off right without any trouble. Bearings will bind, joints will leak, etc., and it takes a little time for everything to get to working nicely.

Joshua Rose says that an efficient method of locating a "pound" in a steam engine is to place one end of a piece of quarter-inch wire, about eight inches long, between the teeth, applying the other end to each end of the crank shaft, bearings, cylinders, &c., the violence of the shock in the vicinity of the pound being sufficiently the greatest to indicate its whereabouts. Mr. Rose remarks that all the mysterious "pounds" that annoy the engineer may be traced to a want of truth in the crank pin, or a want of being in line of the main parts of the engine, usually the cylinder and main shaft.

Cylinder Lubrication.—There is much trouble caused in connection with cylinder lubrication. In some cases the lubrication is spasmodic, in others it is too limited, and in others there is too much oil fed in. There are cases where animal oil is used in such quantities as to cause many troubles in the boiler, to which the exhaust steam is returned by some kinds of heaters. When mineral oil is used this trouble does not occur; but excessive lubrication with mineral oils is apt to cause leaks, which more than counterbalance the advantages of the scale-removing properties of mineral oils.

There should be used for cylinder oiling the best grades of mineral oils, having a slight proportion of purest animal oil; in which case it is best that the oil be introduced in the steam, drop by drop. By the ordinary way of introducing it into the steam chest direct, it is found that some portions receive more oil than others, and there is a waste of oil. The lubricator shown in Fig. 69 (made by the Detroit Lubricator Manufacturing Co.), meets all of these requirements. It is described as follows: A, oil reservoir; B, steam pipe; C, oil filler; D is a water-feed valve; E, the valve to regulate the flow of oil; F F, a steam tube and condensing chamber; G, a valve to draw off water to prevent freezing; H, the visible feed-water chamber; J, a glass indicator; K, the oil discharge pipe; M, the governor valve; N, a valve to correct unsteadiness in the feed; O, vent.

The steam pipe is tapped with a one-half or three-quarter inch gas tap, to receive the oil discharge pipe. Then it is tapped three feet or more above the cock of the condensing chamber, using one-quarter inch pipe for steam connecting tube, which is to be attached to the top of the condenser, placing a globe valve between the steam pipe and the condensing pipe. To fill the cup the valves D and E should be closed. The valve G open and the water drawn off; then the valve G closed and the cup filled with oil. Then open the valve D, then regulate the flow of oil with the valve E. With this lubri-

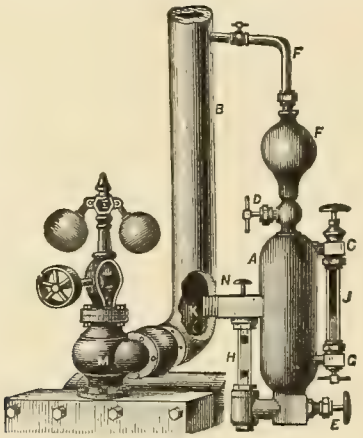


FIG. 69.—SECTIONAL VIEW OF LUBRICATING OIL CUP.

cator the flow is rendered regular, and can be seen passing drop by drop through the transparent water chamber, and it is claimed that it can be regulated to feed only *one drop per minute* when required.

Graphite in Steam Cylinders.—"Having heard of the application of dry plumbago with success, it was concluded to give it a trial. The engine upon which the experiment was carried on was an 11 × 30 horizontal engine, piston speed, three hundred feet per minute, and was known as the "West Poppet Valve Automatic Engine." It was worked up to its full capacity, and, to insure a fair trial, the existing oil cup was exchanged for a goblet-shaped tallow cup with a lid, after which the piston follower and springs were taken out and cleaned. When ready to start the engine, one-third of an ounce of finely powdered Ceylon plumbago was placed in the cup. As soon as the engine was fairly under way, the valve of the grease cup was

opened half way; after running some time it was opened all the way. When the engine was stopped at noon, on examination of the grease cup, the plumbago had all passed into the cylinder, of which there had been strong evidence soon after starting, as the piston rod became coated with it. Upon starting up in the afternoon, one-third of an ounce more was placed in the cup, and the engine run until six o'clock, with a similar result. There was no noise in the cylinder, either in the starting, running or stopping of the engine; and after eighteen months' use, with the above named quantity applied twice a day, no noise has been heard in the cylinder, except when the steam was shut off for the purpose of stopping the engine, when it would be heard during one or two strokes of the piston, just before the engine stopped. This occurred not oftener than would have taken place if tallow or oil had been used. Soon after beginning its use a portion of the plumbago would be found remaining in the cup; to obviate this, about an ounce of water was poured into the cup after the plumbago had been put in, when a decided improvement was observed—so much so, that it can now be fed into the cylinder as readily as oil or tallow. After four weeks' use, the cylinder-head was taken off, and the working part of the cylinder was found coated with plumbago, which could not be easily rubbed off with the fingers; the interior of the piston was found as clean as when it left the lathe, so far as dirt of any kind was concerned, and such is the condition to this day."—*Cor. American Machinist.*

Indicator Diagrams and Expert Tests.—The indicator shows the performance, condition, power and economy of the steam engine; the power wasted by want of lubrication, improper alignment of shafting, badly designed gearing, slip, or excessive tightening of belts. It can be used to register the amount of power consumed by each tenant or machine; detects carelessness or incapacity of the engine runner; points out leaks, chokes, bad packing, condensation, uneven or badly-timed valve motion, etc. The indicator diagram shows the pressure in the cylinder at every point of the stroke, points of cut-off, release and exhaust closure, the loss between the pressures in the boiler and cylinder and condenser, the power developed in the cylinder. When the weight of steam delivered to the cylinder is known it can show the percentage of steam accounted for up to the release. It is not safe to estimate the economy of performance entirely from the indicator diagram, because leaks into or out of the cylinder cannot be thus measured, and when the engine leaks the diagram will show too high a duty. It generally pays to have the engine and boiler overhauled by an expert, and certain portions altered or renewed. In one case known to the writer a change of the cylinder saved one third of the fuel. "The Prony Brake," or friction brake, and the dynamometer, measure with sufficient accuracy the power developed by a motor, and are valuable to check the indicator. Engines rated by their builders at 100 H.-P., with 22½ pounds of steam per hour per H.-P., are sometimes found by indicator or brake to develop but 75 H.-P., consuming 30 pounds of steam hourly. In each case 2,250 pounds of steam is used, and probably 250 pounds of coal burned; but in the second instance both power and economy are too low, and might

sometimes be brought to proper capacity and duty simply by resetting the valves. Engines having irregular motion, causing great loss in cotton factories, paper and flour mills, etc., can always be brought to proper performance by intelligent treatment, after using the indicator to reveal

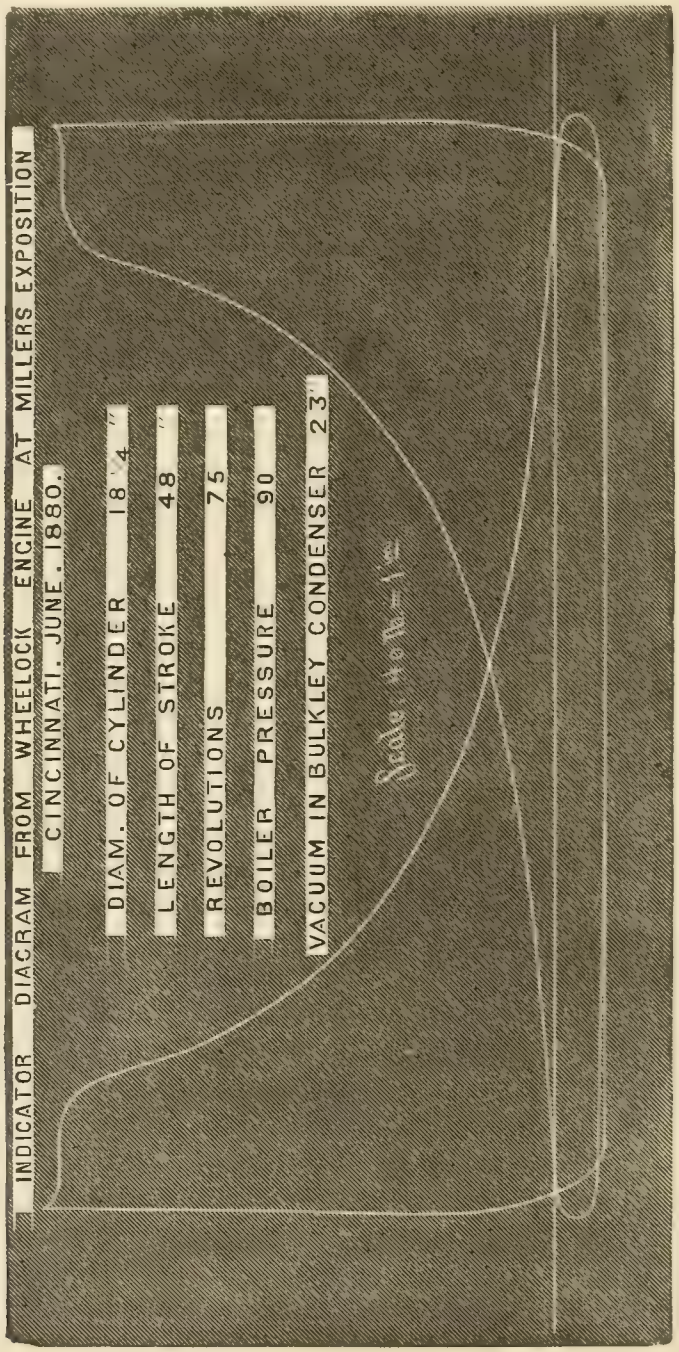

INDICATOR DIAGRAM FROM WHEELOCK ENGINE AT MILLERS EXPOSITION
CINCINNATI. JUNE. 1880.
DIAM. OF CYLINDER 18 4"
LENGTH OF STROKE 48
REVOLUTIONS 75
BOILER PRESSURE 90
VACUUM IN BULKLEY CONDENSER 23
Scale. 40 lbs. = 1"

FIG. 70.

the cause. Regularity is especially important to those using the electric light. Non-condensing engines that are wasteful by reason of back pressure, may at times be made economical by the application of an ejector condenser. The technical papers are constantly receiving such

communications as the following: "I have recently taken charge here as superintendent, and I find the engine not working well. It appears to draw more steam at the head end of the cylinder than at the crank end. It works with a struggling, jarring sound, and certainly is using more steam than the amount of machinery warrants. I am seeking for the diagnosis, so as to apply the proper remedy. Will some of your correspondents throw in a little help?" The expert can help such cases by straightening out the faults in the engine, and seeing that the superintendent gets a competent man to run the engine.

Wheelock Engine.—In the Wheelock Engine, Figs. 71, 72, 73, 74, 75, 76 and 77, the principal peculiarity is the valves, all of which are on the lower side of the cylinder, instead of there being two admission valves above and two exhaust valves below, as is the case with the various Corliss types. There is at each end one main valve performing the functions of an ordinary slide-valve without the friction of the latter. This main valve allows steam admission and exhaust. Upon the back of each main valve there is a cut-off valve, having a cavity in its face allowing double admission and consequent rapid closing. The cut-off valves are well opened before the main valves are ready to open their induction ports. This is an advantage, especially where steam follows but a short portion of the stroke; for if the cut-off is open but a crack, as in cases where the lead is controlled by the cut-off, the mechanism is frequently not sufficient to close it, and steam sizzles through the entire stroke, thereby causing irregularity of motion. The valves are somewhat conical, so that any wear in diameter may be taken up by slight end adjustment. They are hung upon ordinary steel trunnions in hardened steel bushings, so that they do not really touch their seats but are held in steam-tight contact without friction and wear. The steam pressure keeps the collar of the valve stem in contact with the bushings, forming a joint with the steel valve stem or trunnion, thus doing away with the necessity of a stuffing box. This arrangement of valve reduces the clearance to a minimum, and also, as before stated, guards against a waste of steam through the exhaust port, if there should be any leakage pass the cut-off valve. The work of removing the cut-off valves is not performed by the governor, but that important feature simply indicates the point at which the "crab claw" liberates the cut-off. The cut-off is worked from the cramp of the main valve, the connection to the latch link being made by an eccentric bolt, making adjustment very handy and producing the benefits of the celebrated "wrist" motion, without its usual complications. The steam chest is underneath and cast in one with the cylinder, as is also the exhaust passage. The latter is entirely separated from the steam chest, and, while in no way influencing the live steam, should easily dispose of any accumulation of water. The cylinder has only one port at each end, and the valves being suspended should not gouge out the seats, nor do the latter need to be reset. The object of this construction is to get the effect of steam balancing, without the objections that apply to that method. The steel stems have been found in practice to wear endwise in about equal ratio with the surface of the valves and their

seats, and as the valves are suspended with the surfaces in slight contact, while the pressure causes the valves to tend to their seats, durability is obtained.

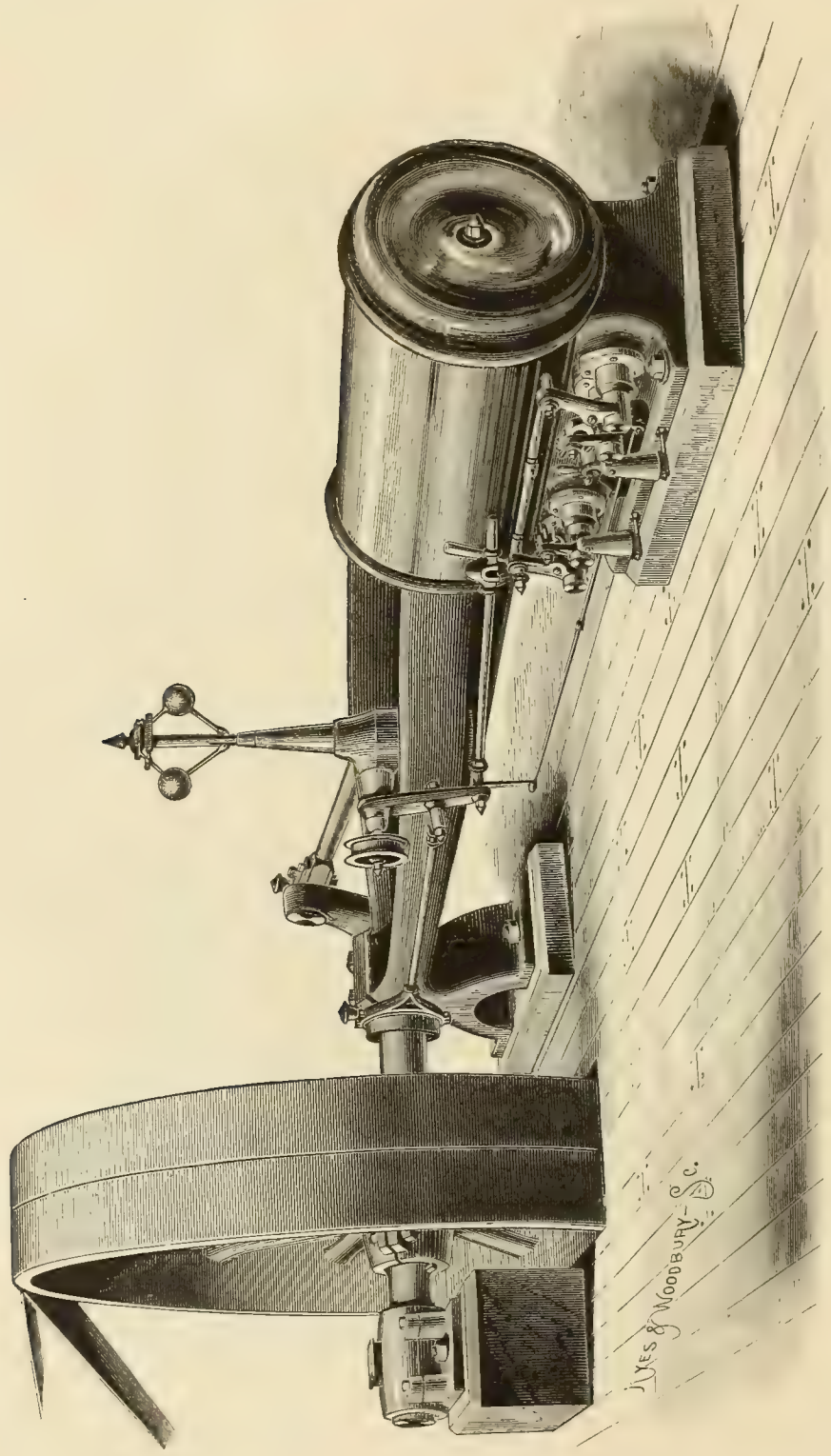


FIG. 71.—NEW FORM OF WHEELOCK ENGINE. PERSPECTIVE VIEW.

The new form of throttle valve, Fig. 73, has points of advantage—that the steam is always on that side which will press the valve to its seat. The stem has a

collar in contact with the inner shoulder of the bonnet, doing away with the stuffing box. As the screw is made to push the valve from its seat, it forces the collar against the shoulder, and makes a tight joint and swivel valve, without rattling when partly shut, the pressure on both the valve and the

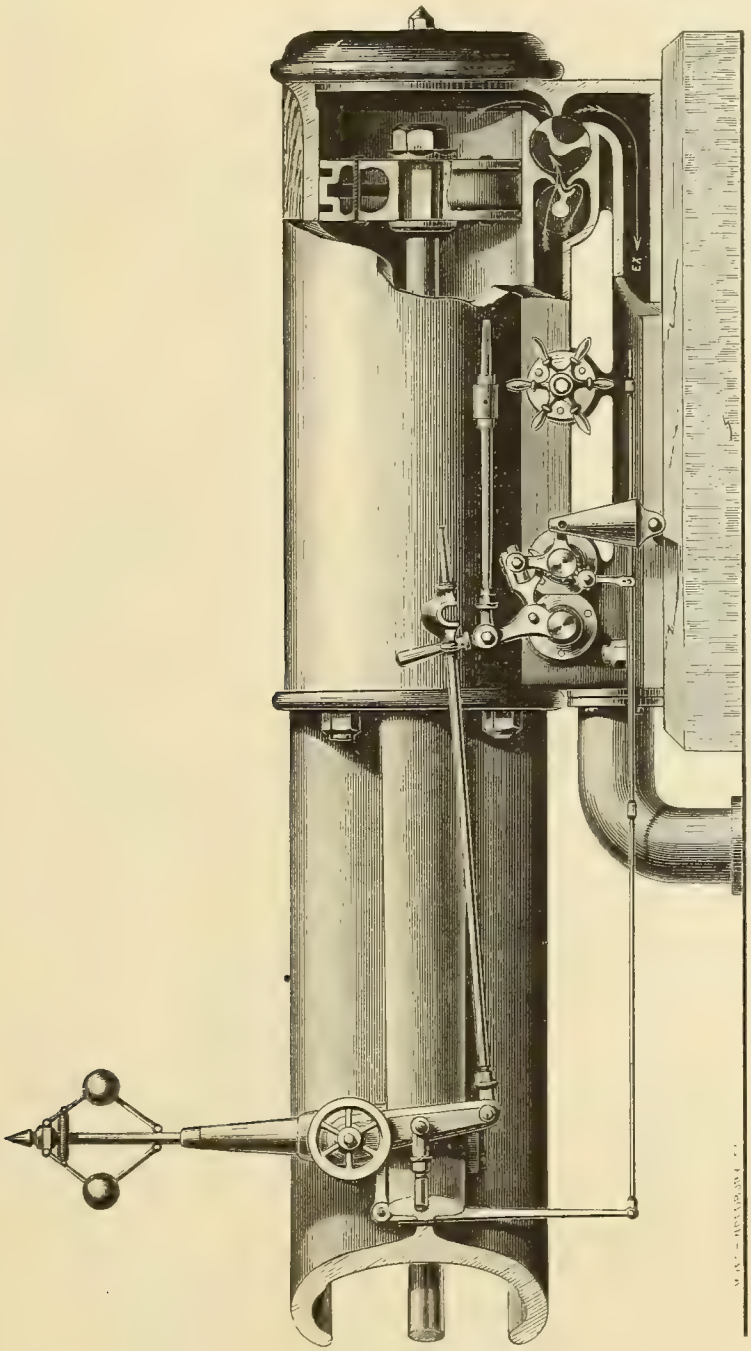


FIG. 72.—WORKING SIDE, PARTLY IN SECTION.

stem being always toward the atmosphere. The other details of the engine embody many tested novelties, resulting from a knowledge of the wants of the simple, durable and easily managed cut-off engine. The piston packing, shown in Fig. 75, is well known in this country, being used by other engine

builders desirous of having a steam-tight packing that will not cut out the cylinder bore.

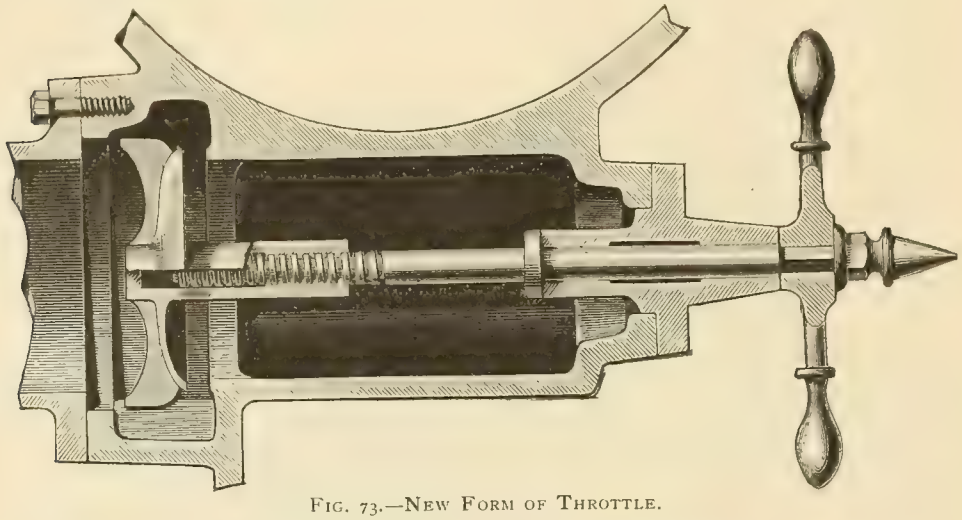


Fig. 73.—New Form of Throttle.

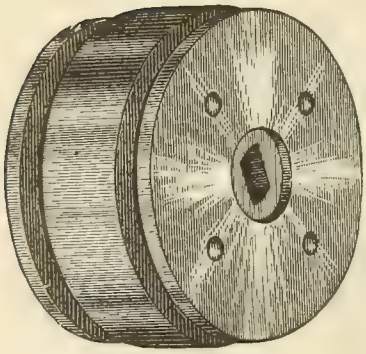


Fig. 74.—Piston Head.

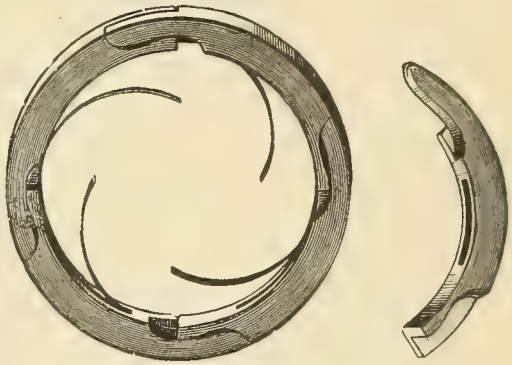


Fig. 75.—Packing Rings.

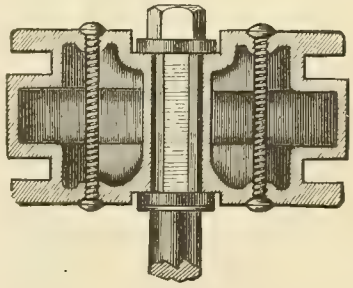


Fig. 76.—Section of Piston Head.

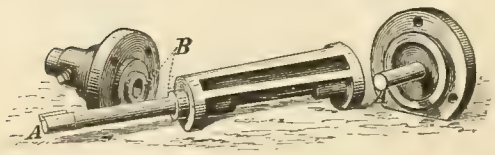


Fig. 77.—Main Valve, Trunnions, &c.

Computation of Horse-Power.—A very neat little formula, easily remembered, for computing the horse-power of a steam engine, is that given

ERRATA.

PAGE 183.—Line five, for "group," read "*crank*."

Line thirty-eight, for "the effective steam pressure," read "the *mean* effective," etc.

Line forty-two, for "space," read "stroke;" for "L," read "l."

PAGE 184.—Line twenty-four, for "*plus* the clearance," read "*less* the clearance."

Formula, line thirty-one, should read, $p = \frac{P\,[l'\,(1 + \text{hyp. log. } R') - c]}{L}$

Line thirty-two, for "mean or average pressure," read "mean or average *effective* pressure."

PAGE 185.—Line thirteen, for "reputation," read "regulation."

by Prof. W. D. Marks, of the University of Pennsylvania. The rule, of course, refers only to indicated horse-power. Let P represent the mean pressure of steam on the piston head per square *inch*, in *pounds*, L the length of stroke in *feet*, A the area of the piston head in *square inches*, and N the number of *strokes* (*i. e.*, twice the number of revolutions of the group) per minute; then (HP) the horse-power, will be equal to $\frac{\text{PLAN}}{33{,}000}$.

This formula is sensible, because the letters spell a familiar word. Those formulas which give a lot of Greek letters bother the average mechanic. It must be remembered that it will not do to be wild in assuming the unit of measurement, as the formula would cipher out different things with feet from the answer with inches. From this very simple formula may be found any one of the five elements if the other four are given. In this we have PLAN given to find horse-power; but we may take advantage of the same relations to find any one of the others. Thus, if we have given the horse-power required, and know the length of stroke of our engine, its diameter or area of piston, and the number of strokes necessary for the engine to run in order to give certain machines in the mill a certain speed, we may find the pressure needed to get this horse-power by the formula $\text{P} = \frac{33{,}000}{\text{LAN}}$ (HP); from the same figures the length of stroke is equal to $\frac{33{,}000}{\text{PAN}}$ (HP); the area equal to $\frac{33{,}000\ (\text{HP})}{\text{PLN}}$; and having given the steam pressure, the length of stroke and the piston diameter or area, we can find the number of strokes needed to get a given horse-power by $\frac{33{,}000\ (\text{HP})}{\text{PLA}}$. In such formula it is the custom not to write the sign of multiplication, it being understood that two letters written together, as A B in a formula, are to be multiplied together Thus, PLAN means P times L times A times N. To avoid confusion, the letters H P are written either as one character, which can be done only in manuscript or by having special types to make this character, or they are written with the parenthesis, ( ), to signify that they denote only one quantity. There are other considerations, such as clearance (or waste space in cylinder and in steam passages), throttling or wire-drawing (reduction of pressure in cylinder, by small and tortuous passages), back pressure, &c., which modify the above figures.

"Factor of horse-power" is a conventional term not much used in the East, and means the product of area and speed of the steam piston, divided by 33,000. Thus, when the area of piston is expressed in square inches, and its speed in feet per minute, the so-called "factor of horse-power" multiplied by the effective steam pressure per square inch, gives the horse-power of the engine. The effective steam pressure, means the mean pressure above the vacuum in the condenser, or in a condensing engine above the mean back pressure in the cylinder, in a non-condensing engine.

Following are more detailed formulas for wok of steam: Let L = length of space in *feet;* L, period of admission, or cut-off, in *feet*, not counting clearance; *c*, total clearance volume at one end of the cylinder in feet of stroke; L′, length of stroke, plus clearance in *feet; l′*, period of admission plus clearance in *feet;* R, nominal rate of expansion; R′, actual expansion rate; A, piston area in *square inches;* P, total admission pressure in lbs. abs. per

square inch (supposed uniform during admission); p, average total pressure in pounds per square inch, during the whole stroke; p_1, average back pressure, in lbs. abs. per square inch, during whole stroke. w, whole work done in one single stroke, in *foot pounds*; w', work of back pressure for one single stroke in *foot pounds;* W, net work done in one single stroke, in *foot pounds.*

To find net work done by steam in the cylinder, for one single stroke of the piston, with a given cut-off: First, find in the table the hyperbolic logarithm of the *actual* expansion rate (allowing for clearance); add one. Multiply the sum by the period of admission plus the clearance, in *feet.* From the product take the clearance (in *feet*). Multiply the remainder by the total admission pressure in lbs. abs. per square inch. This gives total work on the piston in foot pounds per square inch. Second, multiply the average back pressure in lbs. abs. per square inch, by length of stroke in feet, This gives loss by back pressure, in foot pounds per square inch. Third, take the back pressure from the total work; this gives net work in foot pounds per square inch on the piston. Fourth, multiply piston area in square inches by net work per square inch, to get net work in foot pounds done in the cylinder, for one single stroke or one-half revolution.

To find what initial pressure is requisite to produce a given average pressure per square inch, for an actual (not nominal) expansion rate, divide the product of the average total pressure in lbs. abs. per square inch, for the whole stroke, by the stroke in feet; and divide the product by one, plus the hyperbolic logarithm of the *actual* expansion rate, times the period of admission, plus the clearance in feet; the clearance being taken from the product before using it as a divisor. Written as a formula $P = \frac{p\,L}{l'\,(1 + \text{hyp. log. } R') - c}$. To get the average total pressure in the cylinder, *in terms of the initial pressure*, for a given actual expansion rate: divide the stroke in feet into the difference between the clearance in feet, and the period of admission plus clearance, times one plus the hyperbolic logarithm of the actual expansion rate; and multiply the quotient by the total initial pressure in pounds per square inch. As a formula $p = \frac{P\,[\,(1 + \text{hyp. log. } R') - c]}{L}$.

To find the mean or average pressure, take the average back pressure from the average total pressure.

To find the admission period requisite for a given *actual* expansion rate, divide the length of stroke plus clearance, by the actual expansion rate, and deduct the clearance from the quotient.

Power and "Duty."—The power of an engine means how much work it will do, irrespective of how much coal it takes to do this work; the duty is the amount of work it can do with a given amount of steam.

The theoretically perfect steam engine ought to yield us, for every pound of coal burned, $5\frac{1}{2}$ horse-power. By comparing these conclusions with the results of practice, we will see how far from perfection our steam motors really are. The actual consumption of fuel per hour per horse-power will, of course, vary largely in practice, according as the apparatus is well or badly constructed, and properly or wastefully operated. But, putting such disturbing elements aside, we will take the best results of the best practice in

making a comparison. Taking marine engine practice, which gives us the best results, the best of these require from $2\frac{1}{2}$ to 3 pounds of coal to develop a horse-power. As one-fifth of a pound of coal should develop this mechanical effect, if all of its heating effects were realized, it is evident that our best steam engines are only realizing $1\text{-}5 \div 2\frac{1}{2} = 2.50$, or, say, about one-twelfth, or about 8 per cent. of what theory shows us should be realized.

In buying an engine, have its duty guaranteed in pounds of dry steam per hour per horse-power, *not* in pounds of fuel; as in the first case the engine alone determines the stated economy, and in the second, the boiler performance is included; varying with the kind and condition of boiler, manner of setting, covering and firing, quality of fuel, draught, temperature and kind of feed-water, etc., etc. Its rating should be guaranteed under some stated pressure, point of cut-off, and variation of load; and its "repilation" should be guaranteed under certain conditions of variations of load and of boiler pressure. For instance, in a 350-barrel mill, having 80 to 85 pounds boiler pressure, and average load 150 to 175 horse-power, with occasional demand for 200 horse-power; in buying a non-condensing automatic cut-off engine, it ought to be guaranteed at 24.5 pounds of water per hour per horse-power, under one-fifth cut-off, giving 35.2 pounds mean effective pressure, and speed not to vary over two per cent.

The economy rate may be found by dividing 859,375 by the *volume* of steam at the determined pressure, and by mean effective pressure. 859,375 is the number of pounds of water an engine would use to develop one horse-power, if run by water at one pound pressure per square inch. With higher pressure the requisite rate of water would be less; and with steam the amount would be as much less as the volume of the steam at the pressure *at which it is* released is greater than that of an equal weight of water. One H.-P. = $33{,}000 \times 12 = 396{,}000$ *inch* pounds; or say 23,760,000 cubic inches of water per hour per horse-power, for an engine having 396,000 cubic inches per minute piston displacement. One pound of water takes up 27,648 cubic inches; and 23,760,000 divided by $27{,}648 = 859{,}375$.

Cost of Putting in Steam Power.—The cost of 50, 100 and 250 horse-power engines of one of the Corliss types has been estimated by the builders at $6,000, $10,000 and $22,500 respectively, all ready to run, including building, chimney and foundations. The 50 and 100 horse-power would be high pressure and the 250 horse-power condensing.

Cost of Fuel per Barrel of Flour.—The query is often made: "What should be the expense of fuel per barrel of flour?"

This is a question which cannot be answered "on sight," nor even at leisure without fuller details than have yet been placed at our disposal. The expense naturally depends on many elements, the principal ones being the capacity of the mill, the kind of wheat operated upon, the process and machinery employed, grades made, system of transmission, excellence with which this system is carried out, thoroughness of lubrication, and last in order of naming, but not least in importance, the class of engine which furnishes the power, of boiler which supplies the steam, and kind, grade and cost of fuel consumed. In flour mills, the question of pounds of coal per barrel of flour

depends somewhat upon the engine, but generally more upon the boiler. Large mills will use less coal per barrel of flour than small ones; some wheat will take more power than others; new process takes more than old, high grades more than low, old mills more than new, complicated mills more than those where the transmission and flow of material are simple. Mills that are well attended to take less than those that are allowed to sag and get out of order all around; slide valve engines consume more than those of the Corliss type; automatic cut-off less than with fixed cut-off; belts less than gears. Small mills have not the chances for petty economies, that is, for percentage economies, that large ones have. If a mill is run in a neighborhood where coal or wood is dear; if the boiler is of an uneconomical type, badly set and ignorantly fired; if the engine is one which wastefully consumes the steam supplied it, and is run by an ignorant or careless engineer; if cumbrous gears or slipping belts are employed in transmission, the shafts are badly hung or out of line, and bearings short or improperly lubricated, the debtor side of the expense account will show a liberal entry under head of fuel, and more enterprising firms who look more closely to these items, will, other things being equal, be readily able to compete in the markets with the mill that wastes fuel. If, however, a firm chooses that fuel which is cheapest in its neighborhood—as for instance, if it burns sawdust or slabs, or slack, or spent tan, where these can be had for next to nothing—if a skilled and careful fireman is employed where wood or coal is used, so as, by frequent stoking and stirring the fires, to get the most out of the fuel provided, an important prime saving is made. If the boiler is of approved type, supplied with pure hot feed, is well set and jacketed, and with a stack of proper height and proportions, the coal bills should show favorably. If the engine is an automatic cut-off of good design and construction, neither too large nor too small for the work performed, properly erected on solid foundations, and handled by an intelligent engineer, who looks to it that no leak, or cutting or undue friction is allowed to continue after being discovered, the mill owner may feel easier about his coal bill than if his profits were being reduced by such a boiler exhauster as is found in too many mills. If a geared mill, the cogs should mesh with true rolling contact instead of sliding roughly upon each other. If belts are used, they should be of proper tautness—neither loosely flapping about nor drawn up by huge tighteners until the bearings are crowded; they should have a smooth, even surface, straight flush joints, and run on pulleys where faces permit perfect contact and good grip. From this point, the question of the quantity and character of machinery employed and process chosen is one requiring too much space to discuss properly at the present time in these pages. In view of all these considerations, we think that the wide range of fuel cost of from three to ten cents per barrel is easily accounted for. In a good mill a slide valve engine will make 100 barrels of flour in twenty-four hours with six cords of wood, with eighty pounds of steam. An automatic cut-off engine will do the same work with three cords of wood, and only fifty pounds of steam, and give better motion. From four to six cords of bass wood should make 200 barrels of flour in twenty-four hours.

From twenty-five up to fifty pounds of coal should make a barrel of flour in large mills with good management. In the average mill, one horse-power per hour may be said to cost about four pounds of coal. A 300-barrel mill driven by steam and consuming 150 horse-power will use about $150 \times 4 \times 24 = 14{,}400$ pounds per day, or 4,320,000 pounds per year of 300 working days, being about 1,928 gross tons. If, by reason of poor arrangement, poor engines, poor boilers, poor transmission, or any or all other causes, there is a waste of only ten per cent., this amounts to 192.8 tons of coal per year, worth, as a minimum, from $400 to $800 in coal alone.

Herewith are annexed some figures referring to automatic cut-off engines: The Minnetonka Mill Company reports making fifteen or sixteen hundred barrels of flour per week from hard wheat by patent process, blowing the bran 150 feet, using an inch pipe with valve wide open for heating the wheat, and carrying power 150 feet with wire cable, for running a wheat elevator, all with less than thirty cords of wood. Where slide valve engines took six cords of wood to make 100 barrels of flour in twenty-four hours, carrying eighty pounds of steam, an automatic cut-off engine did the work with perfect motion on three cords of wood, carrying only forty or fifty pounds of steam. A mill in Manitowoc used, with one engine, four and five-eighths cords of dry maple wood, three feet nine inches long, to 100 barrels of flour; an improved engine made 101¾ barrels per 2¾ cords of wood. A 14 × 35 engine drives six run of stone, three purifiers, two separators, one cockle machine, eleven bolts, one packer, one smutter, and all other necessary mill machinery, using only one and a half cords of wood per day of ten or twelve hours. In Stillwater, six cords of bass wood make 200 barrels of flour. The Minnetonka Mill Company makes 200 barrels of flour with four cords of wood. One automatic cut-off engine, of which we know, averages 100 barrels of flour for each gross ton of coal, or 22.4 pounds of coal per barrel of flour. The larger and lower the grade of the output, the smaller should be the fuel cost per barrel of flour.

CHAPTER XI.

TRANSMISSION—SHAFTING.

Shafting—Turned Shafting—Cold Rolled—Hot Finished—Hollow Shafts—Hangers—Bearings—Torsion—Couplings—Friction Clutch—To Line Up Shafting—Keys.

Shafting.—It is of the greatest importance that the shafting and all the members which go to form the transmission in a mill should be of the proper material, properly designed, proportioned, put up and cared for. At one time the most common material for shafting was cast-iron, but this has gone out of use, as being too heavy and weak, and lacking in uniformity of nature. Wood was once largely used for large shafts, but is now confined to the axles of large vertical water-wheels, &c. Wrought iron, turned in ordinary or in special lathes, is now more used than any other material. One curious thing about the turned shafting business is that, with most makers, no turned shaft is of the diameter that it professes to be, but takes its name from the round wrought-iron bar from which it was turned. It is customary to take off just 1-16 inch in this turning operation, hence "2½inch" shafting is really but 2 7-16 inches diameter, and so on.

As to sizes of shafting, Cresson makes the shaft the size, instead of the *hole* of the pulley, or letting the shaft come what it will, so to speak. The former method is preferable and proper, because most persons ordering shafting have something on hand which they have already bored certain machinery to fit, and when they find the shafting below the supposed size they are obliged to throw away valuable work, and thus lose both it and the time to make new. Some concerns call 1 15-16 inch, &c. (shafting sizes), improperly by the U. S. standard sizes, 2 inches, &c., but in G. V. Cresson's price list each size is printed as it stands, and is made strictly to this size, which prevents endless confusion. There are firms which make standard size shafting regularly. Cresson calls all of the regular shafting sizes by their real and exact names. We are of the opinion that all firms should do this, as there has been great difficulty caused to customers when ordering. If a customer calls for 1½ inch shafting, for instance, the maker is compelled to write him asking whether he means 1½ inch exact or 1 7-16 inch, and this causes a delay which is sometimes prejudicial to the interest of those who wish to order—especially when they are at a distance.

Turned Shafting—Is, of course, subject to defects arising from the material from which it is made, as well as from the lack of skill, care or special appliances in producing it. If the material from which it is turned is not first-class, the surface of the shaft will be likely to show specks and flaws indicating that the interior is in the same condition, and that the shaft is not strong nor homogeneous. It is very rare that shafting is not very nearly perfectly

round at any one point in its length, but it is sometimes found to be of greater diameter at one end or in one place than at another, and more frequently it will be found that out of ten lengths there will be two or three different diameters, all professing to be exactly the same nominal diameter, and all intended to be just 1-16 inch scant of that nominal diameter. This difference in caliper between two lengths in a line gives rise to serious difficulties in coupling the lengths together into one continuous line.

G. V. Cresson, of Philadelphia, gives us the following figures as the results of actual calipering of his turned shafting. The fixtures show very good work. These results were not obtained by choosing the *best* shafting, but by taking the ordinary stock just as it ran, and therefore give a fair average correctness. This establishment makes nothing but shafting and its accessories.

SHAFT = 2.4375″.

3″	from the end	= 2.435″	Minimum difference = 0.002″
2′ 3″	"	= 2.431″	
3′ 4″	"	= 2.432″	
4′	"	= 2.433″	
6′ 2″	"	= 2.432″	Maximum difference = 0.006″
9′ 6″	"	= 2.434″	
12′ 6″	"	= 2.435″	

SHAFT 4 15-16″ = 4.9375″.

11″	from the end	= 4.932″	Minimum difference = 0 005″
3′	"	= 4.937″	
7′	"	= 4.937″	Maximum difference = 0.006″
9′	"	= 4.937″	

Another shaft of 4 15-16″ measured all through 4.932″; therefore maximum difference = 0.005″.

SHAFT 1 15-16″ = 1.9375″.

12′	from the end	= 1.934″	Minimum difference = 0.002″
3′	"	= 1.932″	
5′	"	= 1.935″	Maximum difference = 0.005″
7′ 6″	"	= 1.935″	

SHAFT 1 15-16″ = 1.9375″.

3″	from the end	= 1.932″	Minimum difference = 0.001″
1′ 6″	"	= 1.932″	
4′	"	= 1.936″	Maximum difference = 0.005″
7′	"	= 1.935″	

It will be found that there are few kinds of shaft couplings that will take in and join two lengths of shafting that are not both of the same diameter, and generally that diameter must be absolutely that for which the coupling is made. Variations of 1-200 of an inch in diameter are very common, and differences of 1-100 inch are to be found in any large shop. The surface of turned shafting should be uniformly true and good throughout the entire length, so that pulleys can be fastened on at any point.

One fault that is very common in shafting coming from shops that have no special and first-class appliances for making shafting, is that the lengths are not straight. They may be perfectly round, all of one size throughout

their entire length, and all of the lengths may be of the same diameter; but the lengths may be crooked. It is useless for the buyer of shafting to try to straighten it, for even if he succeeds in getting it into line, as far as he can judge, there will be a strain upon the shaft itself, and upon the hangers and belts and the bearings of the pulleys driven from the shaft, which will work injury and consume power.

Cold-Rolled Shafting.—There is one great disadvantage inseparable from the manufacture of turned shafting, and that is, that the very best and strongest portion is turned off. In most wrought or cast iron the skin is the life of the whole piece. In cast iron, the skin is very much harder than any other portion of the piece, and in rolled iron, the outside layers, having been subjected more to the condensing action of the rolls than the interior, are often more compact, dense and resistant. This outer part, not having a good enough surface for the purpose of shafting, must be thus worked down so as to give the largest possible finished bar, known as turned shafting. Of course there is the expense of turning, which must be borne by the purchaser, and the loss of a certain diameter and weight, which necessitates buying a larger bar. One step in the right direction which does away with the waste of time, metal and money in turning shafting is to re-roll it cold, so that the surface is powerfully condensed and finished finely. The results of such an operation are that the shafting is much stronger for a given diameter, and each size is exactly what it represents itself to be. But there is one objection to cold rolled shafting for some circumstances, and that is that the interior or core is in such a condition of strain that if any portion of this stress is removed, the whole bar is thrown out of shape. Thus if it is desired to key-seat or spline a line of cold-rolled shafting for any great length (as for use in saw mill carriages, &c.), the whole will spring into a bow, and of course be of no use for that purpose.

Hot-Rolled Shafting.—There is one step farther and in the right direction, and that is in the manufacture of hot-rolled iron shafting, in which the round iron bar, instead of being left with an ordinary surface which has to be re-rolled cold, or turned off, is subjected, while yet hot, to the finishing action of burnishing rolls or disks, which give it a fine surface, while at the same time it is claimed to be stronger for a given diameter. In the process of manufacture it is usual to have a small quantity of water to play upon the finishing rolls, and to keep things cool, and the effect of this is to make a small quantity of steam, which oxidizes the surface of the shafting, and forms a rust-proof coating of oxide of iron which is very sightly and useful. Hot-rolled shafting is capable of being key-seated the same as the turned. The thin film of the oxide of iron which covers the surface is the most effectual protection against rust that is known. It corresponds to the coating put on by the process known as "Barffing," invented by Professor Barff for the protection of ornamental objects of iron work, except that the Barff process consists in subjecting the objects to the exposure in a chamber containing superheated steam at high pressure and temperature. This film is not only not destroyed by oxygen, but is not removable by ordinary abrasion.

Hollow Shafts.—We have considered, so far, the materials ordinarily employed, and have mentioned only those shafts in which the material is disposed in a solid form. Where great stiffness and lightness are demanded in the shaft, it should be tubular, because the same weight of metal disposed in a tubular form is very much stiffer to resist lateral bending than if put in solid, and when it comes to resisting torsion or twisting, you can readily see that a plate of iron a quarter of an inch thick and a foot wide will resist twisting better if disposed in the form of a ring or tube than if coiled up solid into a bar. The nearer metal is to the centre of a shaft the less is its power to resist either springing or twisting. This does not mean that a $2\frac{1}{2}$ inch tubular shaft will be as stiff and as strong as a $2\frac{1}{2}$ inch solid shafting; but if the same weight of metal was disposed in a tubular form it would be stiffer and stronger than if rolled up solid. The lighter a shaft is, other things being equal, the weaker it is; that is, the less horse-power it can transmit and the more it will spring by its own weight, by the weight of the couplings and pulleys upon it, and by the thrust of gears or the pull of belts.

But there is one thing about shafting. A shaft of half the weight, running at twice the speed, will transmit just the same amount of power as one of full weight and slow speed. There is, then, an actual economy, built up of many items, resulting from the use of shafting of small diameter running at high speed. First, there is economy in the purchase of the shafting itself; second, a saving in the couplings, which will, of course, be of smaller size; third, the hangers and other supports can be lighter; fourth, the pulleys, transmitting a given power at high speed, will be lighter than those transmitting the same power at a slow speed; fifth, the belts, traveling at a higher speed to carry off a given horse-power, will be lighter than would be required from a slow running shaft; sixth, the flooring required to support a light run of transmitting mechanism may be made lighter than where it has greater weight hung to it or supported by it from below; seventh, modern machinery, being most of it of high speed, will need less counter shafting to take from a high speed shaft than from a slow running line.

Hangers.—All hangers should be adjustable, so that whatever sag or lack of alignment may be in the building may be readily taken up as fast as the building settles, and whatever sag in the line cannot be taken up can be at least partly counteracted by the ball-and-socket bearings.

As regards the distance between hangers, that is a question concerning which no rule can well be laid down. As a general thing, hangers are placed too far apart. The disadvantage of having a great distance between hangers is that the shafting, no matter how strong and stiff, will sag of its own weight; and, secondly, every time that it makes a revolution, every part of this mass, and especially those portions which lie near the surface, becomes subjected to a wrenching motion tending to weaken the shaft, while, at the same time, this constant pounding consumes power.

If you were shown an inch and a quarter shaft hung sixteen feet between hangers, and were told to bend it a quarter of an inch out of true, 175 times a minute, you would conclude that you would have to rig up some especial jigging machine with a good broad belt to it in order to do this; and yet,

whenever you drive a line of shafting too wide between hangers, especially if it is loaded with heavy pulleys and pulled upon by powerful machines below it, you are wasting just as much power as your jigging machine would require to drive it. The driving belt would have to be extra wide in order to drive a line of sagging shaft. This difficulty with shafting is increased by the sagging of the floor or other supports to which the hangers are attached. Hangers may be placed so close together that the shafting will spring very little between them. But if a heavy machine, like a set of bran rolls, weighing 3,200 pounds, is put on the floor directly above one of these hangers, it will be seen that the line of shafting must be somewhat sagged by the springing of the floor, and more power will be consumed to drive it than before. These are facts which are not only self evident, but have been proved time and time again by the indicator and the friction brake.

Bearings.—As regards the bearings of shafting, they can hardly be made too long. A two-inch shaft should not have less than seven-inch bearings; although only first-class establishments turn out hangers having any such length of bearing surface. Next to the length of the bearing surface

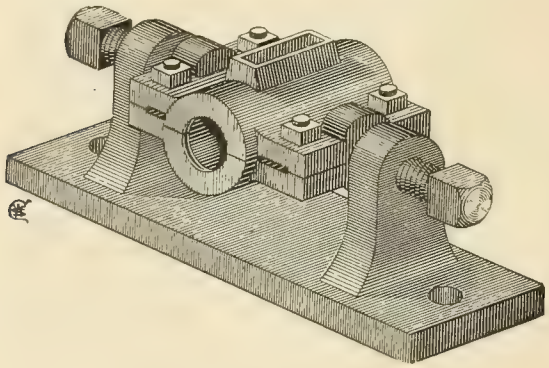


FIG. 78.—PIVOT-BOX.

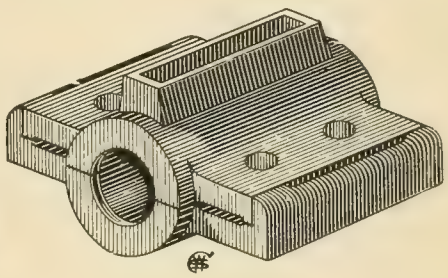


FIG. 79.—JOURNAL-BOX.

comes the question of the material of the bearings. Phosphor bronze anti-friction metal is probably the best in which a shaft can run. It will wear longer, take less oil and preserve the shaft better than anything else. But there are many places where it cannot be obtained, and next to it comes babbitt-metal (that is, *real* babbitt-metal), as the proper thing to use. There are a great many pigs of cheap lead alloys sold under the name of babbitt-metal, and which it is a waste of money to buy.*

Figure 78 is a strong form of pivot-box for shafting. Figure 79 is the ordinary journal-box in which the shaft extends into and below the plate.

Figure 80 shows boxes entirely above the plate.

Figure 81 shows a rigid self-oiling post journal-box for heavy line shafts.

* Very often it is found, in changing a length of shafting from one position to another, that the coupling or the bearing or the pulley bore is too large or too small. This is because the job was made either by the old style of millwrighting, where each day's work was a job by itself, to be considered entirely independent of any other job that had been or would be done on the same or different class of work, or perhaps was done in some "slouch shop" where they are too mean or too careless to have a standard system of gauges; or, giving the establishment or establishments from which the shafting and the coupling and the hangers and the brasses came from, all due credit, perhaps they had been using their standard gauges for actual measurement, instead of keeping them free from wear to compare copies made from them for every day use.

Torsion.—If we know the force in pounds per square inch that it takes to shear any material, then that required to break a cylinder of it by torsion would be the leverage in inches, divided into half the shearing force in pounds per square inch, times 3.1416 times the cube root of the cylinder area

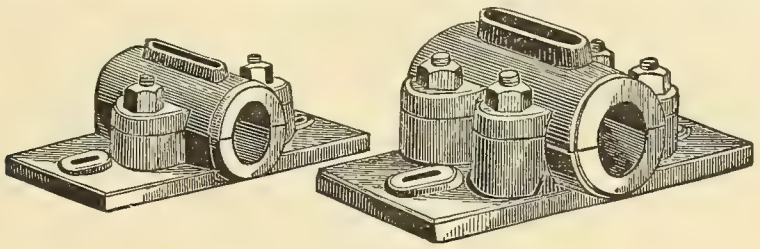


FIG. 80.

in inches. A square shaft is about one and one-fifth times as strong against torsion as a round one, and one-fifth less than a round, hollow one of the same sectional area. Hollow shafts resist torsion better than solid ones *of the same area of metal.* Wrought-iron shafting, supported at eight or nine

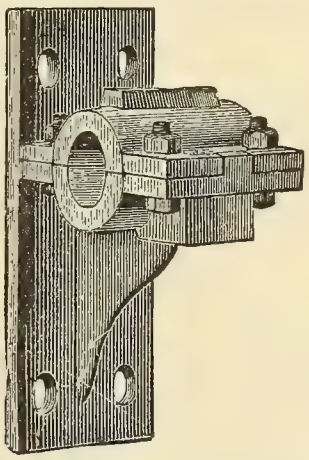


FIG. 81.—SELF-OILING POST JOURNAL-BOX.

foot intervals by self-adjusting hangers, may have a diameter equal to the cube root of the number of horse-powers it transmits, divided by the revolutions per minute and multiplied by 125. The faster shafting revolves *when transmitting a given number of horse-powers*, the less the torsional strain.

Couplings.—In the matter of couplings there are perhaps more engineering botches perpetrated in the way of shaft couplings than in any other line known to mechanics. A shaft coupling should be light, strong, quickly applied, tight-holding, easily taken off ; should not score, dent or mark the shaft, nor require its mutilation by key-sets. It should hold two shafts of the same nominal or actual diameter with just as dead-sure a grip as though they had been turned in one length and cut apart. It should present no projections which would be likely to catch the belts or clothes or any other object. There are such couplings made, but the proportion of them to the engineering botches mentioned is not as great as one in a hundred. The ordinary plate coupling should be absolutely discarded. A key-seat is of no use in coupling. A compression coupling, properly applied, will hold the shaft with a grip that cannot be made to slip, and when it is taken off, the shaft

will be found in just as good condition as before the coupling went on There are some compression couplings, however, the grip of which is almost a permanent affair, and, while they can be put on in ten minutes, they will take a couple of hours to get off.

Line shaft couplings should hold the two ends axially true, hold them entirely equally, and grip the entire length of shafting so tight that it will not work loose by the twisting and turning of the shaft. They should be readily applied and removed, and be light and well balanced. As lathe-turned

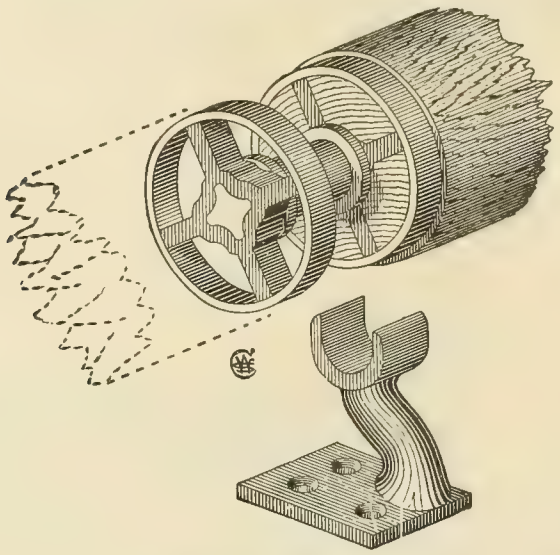


Fig. 82.—Conveyor Coupler and Bearing.

shafting is apt to vary in diameter, there is a further demand for couplings capable of concentric and parallel closure along their entire area, each end being independent of the other. Flange couplings keyed to the shafts, no matter how good the fits are, are bound to be eccentric with the shafts.

There is an innate wickedness in the average shaft coupling, an inborn tendency to get loose, split, wring off, stick fast, &c. It is not reasonable for any one to expect that a line of shafting will keep in good order if hung to the bottom of a springy floor. The shafting should not be put up before the floor has received some if not all its load, especially if there be heavy machines above it, which will, when put up, tend to sag the floor. Where

Fig. 83.—Scarf-Spliced Shaft.

the shafting is attached to cast-iron columns supporting the floor, there is less trouble from sagging, either when the first load is put on the floor or afterward when the building settles. The hanger adds nothing to the torsional resistance of the shaft which it supports. This torsional strength depends upon the length and diameter of the shaft. Some recommend that fly-wheels be put on long lines of shafting, as tending, in a great measure, to equalize the strain of transmission. Some recommend oiling the coupling boxes to diminish friction.

Figure 82 shows a form of coupler intended for connecting two lengths of conveyor shafts, although the same arrangements answer admirably for water-wheel shafts. The bracket which supports it is shown alongside.

Figure 83 shows how to splice a shaft with a scarf.

Figure 84 shows a very common form of plate coupling, each half of which is keyed upon the shaft, the two halves being bolted together. It has the disadvantage of being heavy and dangerous, and disfiguring the shafts at the

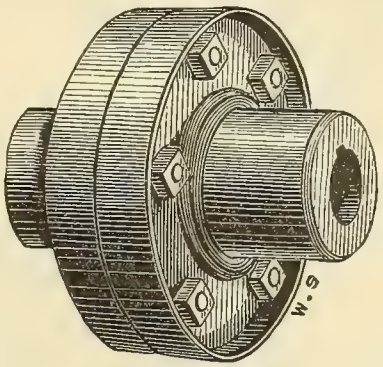


FIG. 84.—PLATE COUPLING.

ends. It is not, however, as dangerous, by reason of catching belts or clothing, as though there were no projecting flanges or rims extending beyond the heads of the bolts.

Figure 85 is a spiral coupler or clutch, a form to be preferred to the

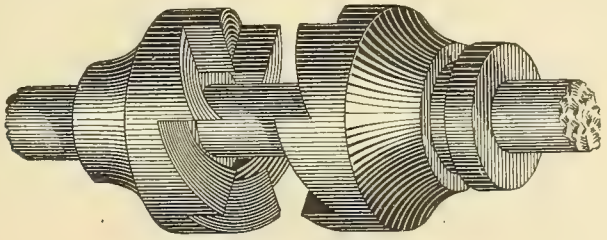


FIG. 85.—SPIRAL CLUTCH.

finger clutch, as being more easily coupled, and with less noise, than the finger clutch when in motion.

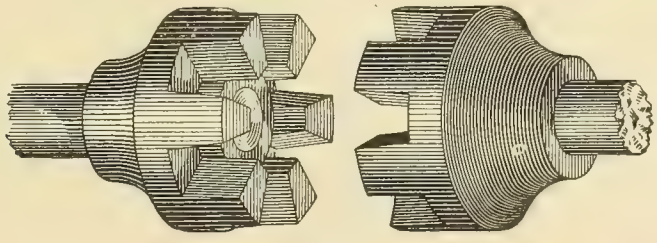


FIG. 86.—FINGER CLUTCH.

Figure 86 is a finger coupler or finger clutch for connecting or disconnecting the ends of two parallel shafts.

Figure 87 shows a wing cushion for the ends of water-wheel shafts. Its construction is clearly shown.

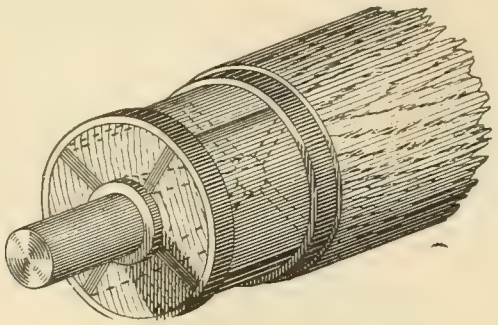


FIG. 87.—WING GUDGEON.

In figure 88 is illustrated a coupling gudgeon which serves the double purpose of gudgeon and coupler.

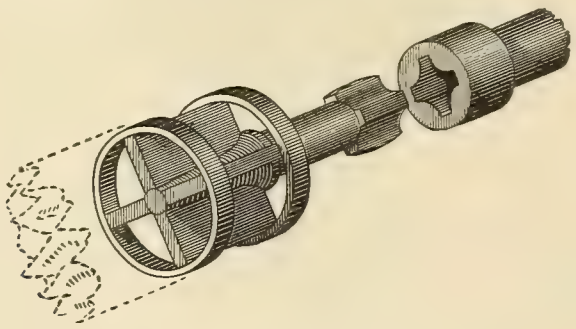


FIG. 88.—COUPLING GUDGEON.

Figure 89 shows a plate gudgeon for the ends of water-wheel shafts.

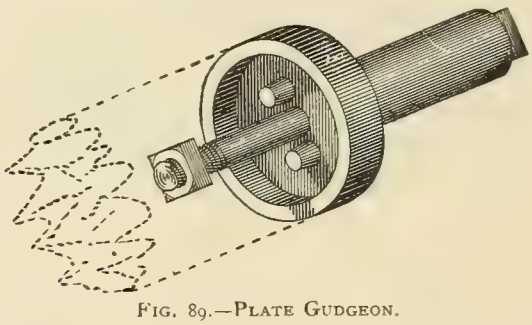


FIG. 89.—PLATE GUDGEON.

Friction Clutch.—In Fig. 90 is shown an adjustable device for mill spindles,* or any machinery driven by a shaft, where it is necessary or desirable to stop or start the machinery without interfering with the motion of shaft.

A is the driving shaft, to which the hub and disc B is keyed fast. The discs C and D are fitted to clamp to the disc B, and are held firmly by the powerful pressure of a number of spiral springs, E, producing severe friction between the discs. Disc C is provided with half coupling, C; when it is intended to engage or disengage motion, the hand-wheel G must be turned (or lever can be used), which, by means of right and left screws

*John A. Hafner, Pittsburg, Pa.

forces the V-shaped coulter wheels, F F, between the discs C and D, thus separating them and permitting the centre disc, B, to revolve freely. This releases the power and stops the discs D and C, so that the half coupling H can be engaged with the extension of the half coupling C, thus communicating motion to the machinery driven by the shaft, I. The clutch

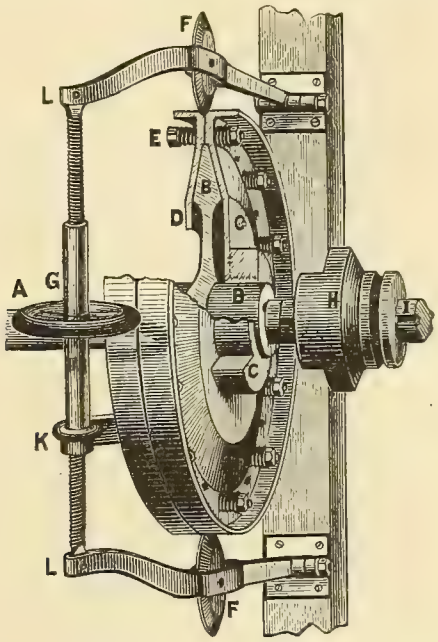


FIG. 90.—FRICTION CLUTCH.

should be held open only long enough to engage or disengage half coupling H, and then allowed to close and run, whether driving shaft, I, or not; thus there will be no wear on the working parts of the clutch. When the clutch is not being operated, the hand-wheel G is supported by the rest, K, so that both V-shaped wheels, F F, are entirely clear of discs. The rim of the clutch is provided with safety flanges, extending beyond the end of the springs, to prevent all risk to any one standing near or operating it. This clutch, it is claimed, can never get out of order, and can be regulated for any desired work or power by the number and strength of the springs which clamp the discs together.

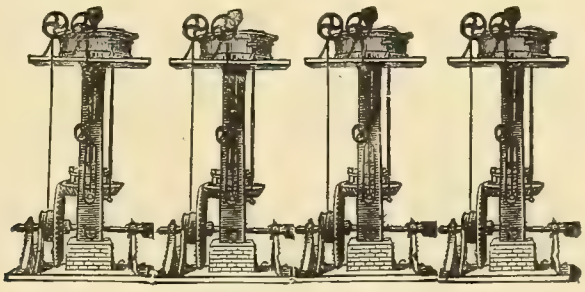


FIG. 91.—CLUTCHES ON LINE SHAFT.

Fig. 91 shows the clutches on a line shaft. The hub of the disc C is turned off, instead of having the half coupling C, and to it the driving bevel wheel is keyed fast. The hand-wheel G is connected with the left hand-

wheel on the grinding floor, so as to operate the clutch, thus stopping the wheel. By turning the right hand-wheel, it will either raise the pinion out of gear or put it in gear, as the case may be. When the miller loosens the first hand-wheel, the clutch closes, starting the driving wheel and running with the shaft, whether it is driving the stone or not. Thus, there is no wear on the working parts of the clutch, and the miller can lighten, start or stop any stone in the mill, and raise the pinion out of, or put it in gear, alone, while on the floor, without stopping the engine.

To Line up Shafting.—Hang a nut or other small weight over the ends of the shaft, by a piece of small twine, so the line passes over the exact centre of the shaft, and the nut is within six inches of the floor. Hang at each bearing or hanger, by pieces of twine, a nut from one side of the shaft, so the nuts are all six inches from the floor. Now stretch a line, one foot high from the floor, from beyond each of the end lines, exactly touching them. The end lines are plumb from the centre of the shaft, and the side lines are plumb from the sides of the shaft. The side lines, when the shaft is in line, must be one-half the diameter of the shaft from the straight line; so move the shaft until the side lines are at that distance; then with a short spirit-level level up the shaft from end to end, and go over each twice, and your shafts will be exactly in line. This can be done at any time, without trouble or expense.

Keys.—In most cases, steel is preferable for small keys, but in some situations soft iron is better, as it hugs the shaft closer than a harder metal can. In olden times, on large water-wheels, there used to be an octagonal hole in the hub, and the shaft, which was correspondingly octagonal, was keyed up by keys driven in alternately from one side and the other. In this way the centre was keyed up evenly all around. Taper keys will throw any shaft out of centre. The straight keys or feathers will not hold anything in place endwise which will not hold itself without such feathers. Still, the taper will lock a movable fit, which the feather will not do, and will also do the only thing a straight key will do, which is to act as a driver.

The entire length of all shafts carrying pulleys or wheels should be turned. Set-screws are a constant source of trouble. The point, only, carries the power, and this often either breaks off or cuts a ring in the shaft.

CHAPTER XII.

TRANSMISSION BY BELTING.

Belts vs. Gears — Elements in Belt Transmission — Rubber Belts — Cotton — Rawhide — Leather — Duration — Requisites for Successful Belt Transmission — Tension — Sag — Tightening Pulleys — Lacing — Putting on Belts — Testing Strength and Grip — Laying Out — Carrying Power around a Corner by a Belt — Shifter.

The almost exclusive use of belts instead of shafts and gears (even the largest), as a mode of transmission of power, is a successful American innovation which has long struck foreign engineers with wonder, but which is now becoming more and more generally introduced, especially where there is competition with American machines. This substitution of belts for gears, even where accuracy in number of revolutions is essential, is largely due to the superiority of American over foreign belts (except in rubber)—this rendering possible a certainty of force otherwise unattainable.

Belts vs. Gears.—Belts are superior to gears for the transmission of power in all cases where the power is irregular. They have the disadvantage of needing more frequent repairs than gears, and of having to be renewed much more frequently. One advantage of belt transmission is that connections may be very readily established or broken at any distance and under any circumstances. Belts should be used instead of gearing: When shafts are very far apart; when there is danger of jamming in machines which are run by conveyed power; when high velocities are used; on any machine that does not require excessive power for its size and extremely steady motion; in conveying power from story to story in mills, etc., where there is any jarring in the machine; or in running tools, so that if the tools catch, belts will slip instead.

Elements in Belt Transmission.—The elements to be considered in belt-driving are pulley diameter, material, crown, condition, revolutions per minute; belt material, condition, tension, arc of contact, thickness, width, lineal speed per minute; distance between pulley centres, position of belt, whether horizontal, inclined or vertical; and whether opened or crossed; and if a single leather belt, which side is run next the pulley.

In belt transmission, three forces are principally concerned: the tension on the driving side, the tension of the driven side, and the adhesion to the pulleys. A. B. Couch puts the whole science of belt-driving very nicely when he says that the difference between the first and the second of these forces is the net force of transmission, and cannot exceed the third.

That arc of contact has often more to do with the driving power of belts than the contact area, is shown by the wire rope, where the area of contact

is so small as to be neglected in calculations, while large arc of contact is absolutely necessary.

When we say *friction* of the belts *upon* the pulleys, we do not of course mean *adhesion to* the pulley. While the one is an absolute necessity, the other is the cause of waste of power. As the resistance to bending is no small matter, it is for this reason better to use broad thin belts than narrow thick ones, and as the resistance to bending decreases as the diameter of the pulley increases, it is for this reason better to use large pulleys, other things being equal. If a leather belt is dry, its adhesion is less than if it were moist. When moist with water, its adhesion is greater than when animal oil is used.

Rubber Belts.—Never under any circumstances let animal oil touch a rubber belt. Mineral oils are even worse, as the naphtha, benzine, etc., which they contain are solvents of rubber. If a rubber belt should slip, the trouble may be lessened or cured by giving it a light coating of boiled linseed oil. If one coating does not completely remedy the fault, try another. "The durability of rubber belts may be increased by giving the surface a light coat of a composition made of blacklead (graphite, plumbago) and litharge, equal parts, mixed with boiled linseed oil and enough Japan to make it dry quickly. This will give a highly polished surface which will bed itself well down to the pulley." Qualities vary greatly, even although prices may be the same, or nearly so. Always buy the best quality (there are three grades made by some manufacturers).

Cotton Belts.—These should be closely woven of the best material. If well waxed they have a high tractile power and wear well. Their light weight prevents their lifting from centrifugal force. They are apt to give trouble from stretching, although some makes are guaranteed against this.

"Rawhide" Belting.—"Rawhide" belting and lace leather are manufactured by a process which differs from that by which oak-tanned leather is made. This leather is not tanned, but is first cured and dressed in oil, etc. The belting is made from green-salted butcher hides, from which the hair is sweated off instead of limed as by the old process. The skins are then cured in a mixture which it is said opens the pores, and when in a semi-dry or samiel condition they are filled with a mixture of tanners' oil and tar, making them at the same time pliable and waterproof. It is claimed that there are no acids nor lime used in its manufacture, and so it cannot eat itself up. The round rawhide belting made by this same process is in fact a rope, made from strips (selected) or strands laid up as an ordinary rope, and is really very pliable—a great desideratum in round belting. Belting of this class is made by the Chicago Rawhide Manufacturing Company.

Leather Belts.—Leather belts are the most common, and the most generally adaptable. The best leather for belting is oak-tanned. There is some belting in the market which is chemical-tanned, but colored in imitation of oak. Good hides may be spoiled in the currying. Leather belts weigh when new about 60 pounds per cubic foot. After that they get a very little heavier.

Duration of Belts.—Leather belts, if well taken care of and used, will last twenty years; rubber eight or ten. One advantage of leather belts is that wide ones can be cut up into narrow ones, and old ones worked up into new. They stand the action of oil, heat, freezing and tearing in machinery better than rubber. Young hides make better belts than old ones. For dry, warm places, belts of coarse, loose leather may be employed; for wet or moist situations the finest and firmest stock should be used. They should be run with the slack side on top. Long belts are better than short ones, except where they are vertical; broad thin ones better for some reasons than narrow thick ones of the same sectional area. There is no use in discarding a belt so long as there are portions of it that can be used to advantage in another place. But new portions must not be put into the old one, as the tension is different.

Requisites for Successful Belt Transmission.—The successful and economical transmission of power by "wrapping connectors" demands great width and large arc of belt and pulley contact; very slight crowning and very great smoothness of the pulley faces; that the belt shall neither slip nor stick; that the tension be neither too great nor too little; that the fastenings be strong and neat; the laps so disposed that the driving motion run with, not against, them; the belts carefully put on and skillfully joined; the pulleys as large, the speed as high, and the belt as light as practicable, and the upper belt fold be slack; the fly-wheel of sufficient weight; the belt uniform in section, weight, and texture; its edges smooth, especially for high running; the pulleys lagged with paper, rubber or leather; single belts reinforced on their outer edges. Belting should be pliable, so as to cling to the pulley and run with little friction. Oiling causes leather belts to stretch. Single leather belting should stand 750 pounds per inch of width, and transmit 55 pounds on smooth, high-speed pulleys. A belt surface corresponding to 600 feet an inch wide, or say 50 square feet in any proportions, passing in a minute with a half-turn around a smooth turned iron pulley of not too small diameter, is said to transmit one horse-power. If once strained by over-work a belt will soon become useless; for this reason wide belts are to be preferred. Wide belts drive better than narrow ones, but not in proportion to the excess of width; especially on small pulleys. One 6″ belt does not drive as well as two 3″, nor twice as one 3″. Double belts, though stronger than single, have not twice their driving power. To carry same power they need to be 3-5 as wide as single. Loss of driving power is largely because of curling up of the edges, which may be prevented by adding a stiffening piece at each edge of a single belt, thus:

New belts (especially leather) do not bed themselves as well to the pulley face as when older. When stiff, or glazed over, or greasy, leather belts again lose driving power. Increase of belt speed increases driving power, but not proportionately, because excessive speed causes flapping and two little often causes slip. Fast belt speeds are better than slow ones for many reasons; one is, they are less liable to slip, and the grip is much

better. Increase of tension increases driving power, but not proportionately. When bearings are ample and efficient, tension may be greater than where poor and insufficient (see special remarks on tightening). The greater the arc of contact the better the drive, but not proportionately.

Experiments made by the author show that when new leather belts are run on new cast or wrought iron rim pulleys, the flesh side grips the best. But old belts on cast-iron pulleys drive best, and last longest, grain side to. Belts should not be too strong. They should be strong enough to carry all the power that is required of them, but weak enough to break before the shaft, pulleys or gears. Wood-working and flouring machinery belts generally have less driving power than others where they can remain soft and pliable, as the fine wood dust chokes up their pores and lessens their pliability.

Where narrow belts are used on small pulleys, the shafts should be about 15 feet apart. For larger belts and larger pulleys, 20 to 25 feet will do. Where there are very large pulleys, 25 to 30 feet will answer. If the distance between the shafts be too small, there will not be enough sag to the belt to make it tight; and if they be too far apart, there will be too much tension upon the belt and too much pressure upon the bearings.

In horizontal belts the under side should be the driving side, so that the upper side may hug the pulley by its own weight.

Tension.—The driving power of a belt may be increased by giving the proper tension, where this does not exist. The best tension for a single leather belt, where the bearing surfaces are good and ample, is 45 to 55 lbs. per inch of belt width.

In the author's regular work, as well as in the Testing Department, he uses Lienau Walden's Tension Registering Belt-tightener, patented May 3, 1881 (Fig. 92). This tightens both sides of a belt alike; puts on any desired tension; shows whether belts in use are too slack or too tight; prevents friction, slip, backlash, waste or loss of power and lubricants, weakening of belts and breaking of fastenings. Belts tightened with it ought to drive better and last longer than if tightened as is ordinarily done. It is easily and quickly applied. It is made in sizes for belts up to 6 inches, 15 inches and 26 inches.

Sag.—Belts have a tendency to sag edgewise, and to leave their proper place upon their pulleys. This is more particularly the case with belts transmitting motion between vertical shafts. When two shafts are not in parallel allignment, the belt from one to the other will tend to work off from one of the two pulleys. There are four ways of remedying this: first, by properly alligning the shafts; second, by placing unyielding guides at the edges of the belt; third, by using special tighteners, and fourth, by giving excessive crown to the pulleys. When belts are used to transmit motion between vertical shafts, the tendency of the belt to work off is aggravated by weight, and this tendency must be met by throwing the shafts out of correct line, by guiding the edge of the belt, or by the use of special tighteners. Between horizontal shafts the weight of the belt transmitting motion tends to cause or increase adhesion. This is not the case between vertical shafts, the belts of which require to be strained by tighteners. The tighteners may be swinging or

sliding, and when properly designed and made the former should be provided with an adjustment by which the pulley can be moved in the plane of its axis, and the housing piece should be pivoted so that the axis may be given an oblique position.

Tightening Pulleys.—The friction of a belt upon a pulley depends upon the pressure or tightness, and upon the number of degrees of contact. Generally, belts running from a large to a small pulley slip on the large and not on the small one. Tightening pulleys are placed on the slack side of the belt near the small pulley. They increase the friction of driving. They should always be as large in diameter and as free as possible. The best tightener

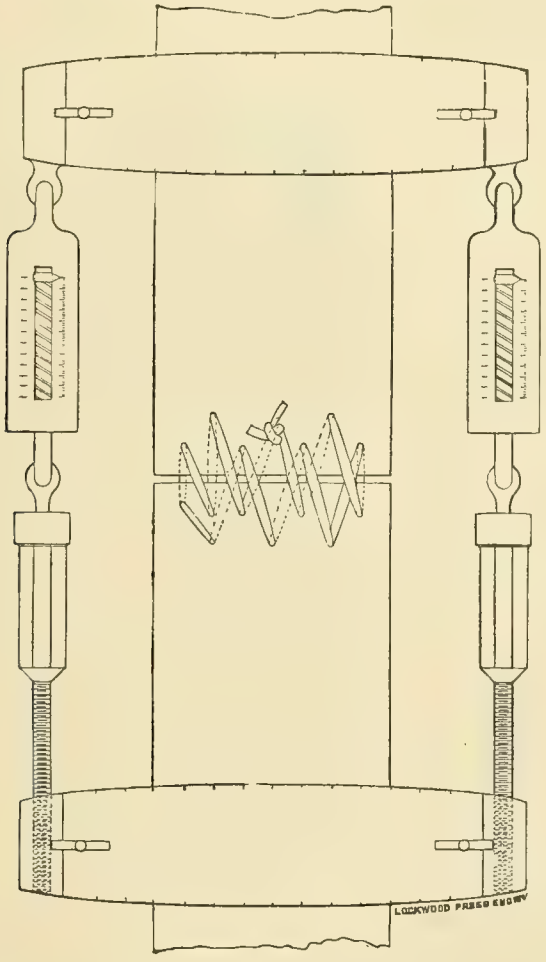


FIG. 92.—WALDEN'S BELT CLAMPS.

is the weight of the belt on the slack side. Loose belts last longer than tight ones. Horizontal and inclined belts are better than vertical and short ones, as requiring less tightening. Fig. 93, on following page, shows an improved tightener, made by the Richmond City Mill Works.

Slipping.—A belt should never be allowed to screech on the pulleys. This causes heating and stretching of the belt. A screeching belt should be hunted up at once and fixed. One writer says: "If rubber belts

grow glassy and slip so as to let down the motion of the machinery, rub them well on the inside with boiled linseed oil—the older and stickier the better. It will not hurt the rubber and will stop the slipping. If the rubber coating wears off, leaving the cotton web exposed to wear, give them two or three coats of white lead paint. Put in plenty of Japan dryer, and it will be found that the belt will wear as well and nearly as long as when first put on. If leather belts are smooth and slippery, a grease made of one part of kidney tallow and two parts of castor-oil (which is a good lubricant, too,* and it can be had cheap of the oilmen or at large drug and paint shops), put on quite warm after the belt has been moistened to open up the pores, will help them vastly. It is a good thing also where there are rats and mice, as they will not gnaw a belt that has this composition on it."

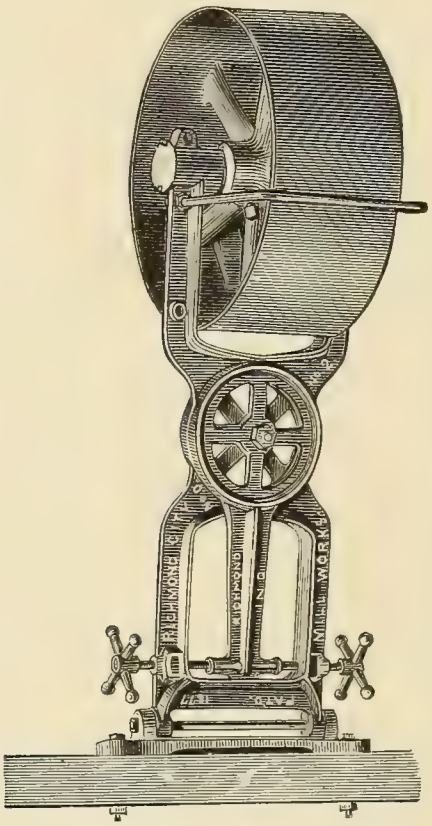


Fig. 93.—Improved Belt Tightener.

Belt Stretching.—A. G. writes to the *Millers' Journal:* "It rarely happens that a man complains that he is getting more stuff than he has paid for, but really I am so much annoyed by my new leather belts stretching that I think I ought to ask if it is not the belting manufacturer's place to take out all the stretch there is before I get it, just as much as it is the tailor's place to shrink the cloth for my trousers all it will shrink before he makes it up. In any case, what is the best way for me to get a good stretch on them when they are being put on the pulleys?" To this the answer was: "The stretch

*Denied *in toto* by the author. Castor-oil is *not* a good lubricant.

of leather belts should be taken out of them in the process of manufacture, but it is often necessary to tighten even the best of them, or take up their slack or stretch. This is best done with two iron or wooden screw clamps with a right and left handed screw rod in the centre (or better yet, one such screw rod at each end to connect the clamps, which brings the belt edge nearer). The clamps may be mounted in a frame which acts simply as a guide." The author uses belt clamps having on each side a spring balance, enabling him to tighten both sides alike (Fig. 92), and to put on the proper tension—say forty-five pounds for each inch of width of single leather belt.

Cement for Leather Belting.—One who has tried everything says that after an experience of fifteen years he has found nothing to equal the following as a cement for leather belting: Common glue and isinglass, equal parts, soaked for ten hours in just enough water to cover them. Bring gradually to a boiling heat and add pure tannin until the whole becomes ropy, or appears like the white of eggs. Buff off the surfaces to be joined, apply this cement warm, and clamp firmly.

The Splice.—It has been asked, Which way should the splices or laps of a belt be run? J. H. Cooper, in reply thereto, says: "The general answer to this question is, Put the belt on so that the pulley in slipping on the face of the belt shall run *with* and not *against* the splices. But if the belt slips on both pulleys, of a belted pair, then, as 'Machinist' says, there can be no difference which way the splices of the belt lie, for the motion of one pulley will be against and the motion of the other will be with the splices, which is a true state of the case, but which does not often happen; there will mostly be conditions favoring slippage on the one or other of the pulleys, and when it is known which one it is, then put the belt on to suit this condition. In the cases where there is no slipping, if the driving pulley acts favorably on the splices, then the driven pulley is sure to be against them, and so it may be said there is really nothing in the advice directing the way a belt should be run, except for the cases of known slippage."

A good rule for the distance between shafts connected by belts is that the distance between the shafts be ten times the diameter of the small pulley. We may say for narrow belts over small pulleys 15 feet is a good average; for larger belts on larger pulleys, 20 to 25 feet. In every case the distance should be such as to give the belt a gentle sag. Belts should be enclosed in neat boxes on each floor. The "Washburn A" mill is the only one in the country driven entirely by belting.

Lacing.—Belts should have only one laced joint. If they must be made of several pieces, only one of the joints should be laced, the ends of the others being beveled (if of leather) and permanently fastened. Fish glue will not splice old, oily belts. The ends of the belt must always be cut square. To cut and join a belt do not take it off the pulley unless necessary. Lace leather will pull and stretch under a straight edge.

The belts should be placed on the pulleys as tight as possible. This can be best done by the use of belt clamps, except in the case of very narrow belts. In all cases the belt should be cut about one eighth of an inch less than the distance around the pulleys with the tape line. The seam of the

The following are the results of tests by the author on the belting of the New York Belting and Packing Co., 37 Park Row, N. Y., expressly for this work:

Date.	No.	Width Inches.	Plies.	Dist. betw'n Grips—Inches.	Broke—Pounds.	Strength per Inch wide—lbs.	Strength, Inch Wide, 1 Ply—lbs.
Mar. 4	1	2	3	8	1,690	845	281.66
April 28	2	2	2	8	1,190	595	297.5
"	3	3	4	8	3,030	1010	252.5
"	4	4	3	8	3,030	757 5	252.5
"	5	4	2	8	1,950	487.5	243.75
"	6	4	4	8	3,750	937.5	234.37
"	7	8	4	8	6,540	817.5	204.37
"	8	12	4	8	8,520	710	177.5
"	9	12	3	8	6,400	533.5	177.76
May 4	10	6	4	8	5,010	835	208.75

Average, 233.24 lbs.

GRIP TESTS OF NEW YORK BELTING AND PACKING COMPANY'S RUBBER BELTS.

Date.	Office Number.	Width, inches.	Pulley diameter, inches.	Plies.	Arc of Contact, degrees.	Tension, lbs.	Grip, lbs.	Grip per inch width.	Grip per inch width per quadrant.	Grip per inch per lb. tension	Grip per inch per lb. tension per quadrant.
July 28	1599	3½	36	4	90	195	260	74.28	74.28	.38	.38
"	1600	3½	36	4	90	400	366	104.57	104.57	.27	.27
"	1601	3½	36	4	180	195	460	131.42	65.71	.67	.33
"	1602	3½	36	4	180	400	805	230.	115.	.57	.28
"	1608	2	36	4	90	195	181	90.5	90.5	.46	.46
"	1609	2	36	4	90	400	332	166.	166.	.415	.415
"	1610	2	36	4	180	195	387	193.5	96.75	.99	.49
"	1611	2	36	4	180	400	605	302.5	151.25	.756	.3781
"	1613	6	36	4	180	195	699	116.5	58.25	.59	.29
"	1614	6	36	4	180	400	944	157.33	78.66	.39	.19
"	1615	6	36	4	270	195	899	149.83	49.94	.76	.25
"	1616	6	36	4	270	400	1294	215.66	71.88	.53	.17
"	1617	6	24	4	90	195	221	36.83	36.83	.18	.18
"	1618	6	24	4	90	400	450	75.	75.	.18	.18
"	1619	6	24	4	180	195	331	55.166	27.583	.28	.14
"	1620	6	24	4	180	400	644	107.333	53.666	.26	.13
"	1621	3½	24	4	90	195	199	56.85	56.85	.29	.29
"	1622	3½	24	4	90	400	368	105.14	105.14	.26	.26
"	1623	3½	24	4	180	195	384	109.71	54.85	.56	.28
"	1624	3½	24	4	180	400	744	212.57	106.28	.53	.26
"	1625	2	24	4	90	195	224	112.	112.	.56	.56
"	1626	2	24	4	90	400	394	197.	197.	.49	.49
"	1627	2	24	4	180	195	415	207.5	103.75	1.06	.53
"	1628	2	24	4	180	400	744	372.	186.	.93	.46
Sept. 13	1751	6	24	4	270	150	394	65.66	21.88	.436	.145
"	1752	6	24	4	270	200	494	82.33	27.444	.411	.137
"	1753	3½	24	4	270	150	410	117.142	39.047	.780	.260
"	1754	3½	24	4	270	200	491	140.285	46.761	.701	.233
"	1755	2	24	4	270	150	379	189.5	63.166	1.33	.44
"	1756	2	24	4	270	200	495	247.5	82.5	1.23	.41
Sept. 16	1830	3½	18	4	90	150	115	32.857	32.857	.2190	.2190
"	1831	3½	18	4	90	200	160	45.714	45.714	.2285	.2285
"	1832	3½	18	4	180	150	192	54.857	27.428	.3657	.1828
"	1833	3½	18	4	180	200	289	82.571	41.285	.4128	.2064

The following figures show the strength and driving power of ordinary and waterproof leather belting (made by E. F. Bradford & Co., Cincinnati) according to tests made by the author especially for this work:

BREAKING TESTS OF E. F. BRADFORD & CO.'S LEATHER BELTING.

Date.	Office Number.	Material.	Length, inches.	Width, inches.	Breaking Strain—lbs.	Breaking Strain, per inch width.
May 6	1161	Leather.	18	8	6040	755
June 21	1162	"	"	6	7090	1181.66
"	1163	"	"	8	9100	1137.5
"	1164	"	"	12	11,550	962.5
"	1168	"	"	$2\frac{1}{3}$	2540	1197.14

Average, 1046.79.

GRIP TESTS OF E. F. BRADFORD & CO.'S LEATHER BELTING.

Date.	Office Number.	Side to Pulley Face.	Width, inch.	Pulley Diameter, inches.	Arc of Contact, degs.	Tension, lbs.	Grip, lbs.	Grip per inch width, lbs.	Grip per inch width, per quadrant.	Grip per inch width, per lb. tension.	Grip per inch width, per lb. tension per quad.
Sept. 9	1713	Flesh.	6	24	180	195	123	20.5	10.25	.105	.0525
"	1714	"	"	"	"	400	202	33.666	16.833	.841	.420
"	1715	Grain.	"	"	"	195	115	19.166	9.5833	.982	.491
"	1716	"	"	"	"	400	119	19.833	9.9166	.247	.123
"	1717	F.w.p	"	"	"	195	124	20.666	10.3333	.159	.079
"	1718	"	"	"	"	400	264	44.833	22.4166	.112	.056
"	1719	G.w.p.	"	"	"	195	99	16.5	8.25	.084	.042
"	1720	"	"	"	"	400	200	33.333	16.6666	.084	.042
Sept. 17	1852	"	"	18	"	200	110	18.3333	9.1666	.0916	.0458
"	1853	F.w.p.	"	"	"	200	144	24.	12.	.12	.06
"	1854	G. p.	"	"	"	200	94	15.6666	7.8333	.0783	.0391
"	1855	F. p.	"	"	"	200	144	24.	12.	12.	.06

Belts should be bought of reputable dealers only, and only reliable makes purchased. The manufacturers above quoted are recommended with confidence.

Laying Out.—In driving a line of shafting on one floor from the one above or below, the best results are obtained when the pulleys are of the same size, and not greater in diameter than twice the width of the belt, the vertical distance between the shaft centres being not less than three feet for every inch of belt width.

Figure 96 shows the method of laying out holes upon the floor for quarter-turn belts. That fold of the belt which leaves the face of one pulley must approach the centre of the face of the other in a line at right angles to the

axis of the latter. Where *a*, *b*, *c* and *d* intersect will be the place where the centres of the folds of the belt will pass when drawn tight and at rest.

Figure 97 shows the manner of cutting holes through floors for belts. A B represent the floor, C the pulley, and *d* the drum. Drop a perpendicular from the centre of the pulley at *e*, and measure the distance, which we will call 30 inches. Drop a plumb-line from the floor to the centre of the drum,

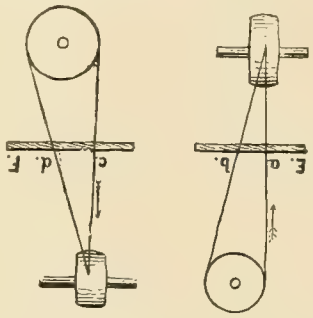


FIG. 96.—LAYING OUT HOLES FOR QUARTER-TURN BELTS.

as at *f*, and note the distance, which we will call 18 inches. At *f* make small trial hole through the floor, from which measure the distance from the perpendicular *e*, which we will call 34 inches. Then, on the floor draw a line to represent the floor, A B, raise the perpendicular *e*, and set off the distance, 30 inches, and describe a circle 30 inches in diameter to represent the pulley. Measure off 34 inches from *e*, draw the perpendicular *f*, set off the distance,

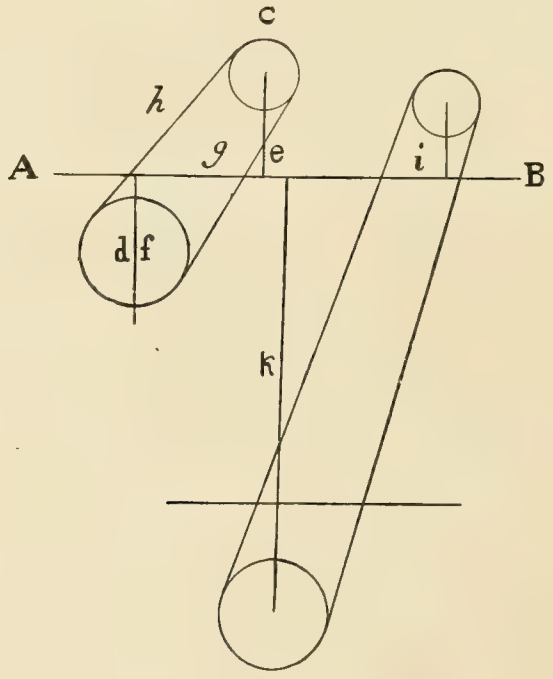


FIG. 97.—CUTTING HOLES IN FLOORS FOR STRAIGHT OPEN BELTS.

18 inches, and describe a circle 24 inches in diameter to represent the drum *d*; then draw the lines *g h*, to represent the belt, and where *g* and *h* cross

the line A B, the holes are to be cut, about one half larger than the belt each way, which may be transferred from the plane to the place first mentioned.

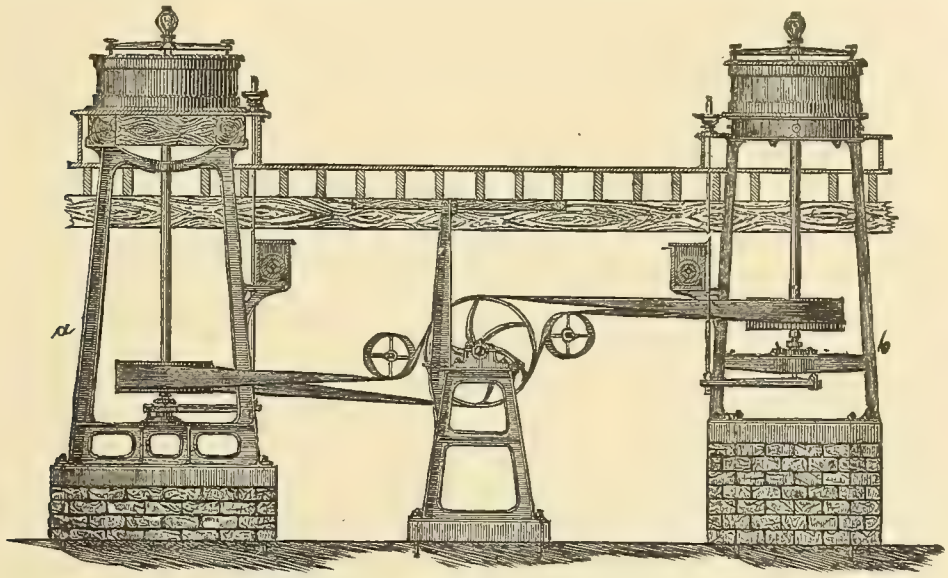


FIG. 98.—METHOD OF DRIVING TWO LINES OF BUHRS FROM ONE SHAFT.

Figure 98 shows the method of driving two lines of stone from one shaft, *a* being the hurst, cast in one piece, with timber top, and *b* a hurst cast in one piece with iron top. (The first method with timber top is preferable.)

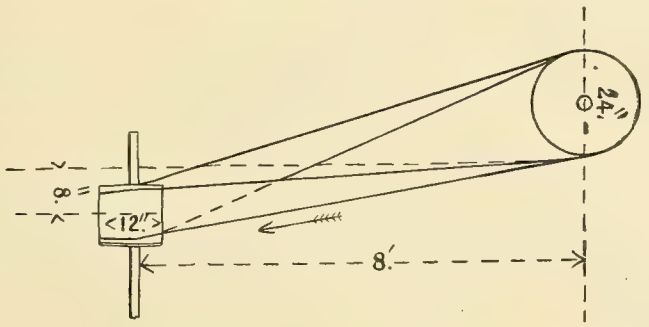


FIG. 99.—QUARTER TWIST BELT.

In Figure 99 the centre of the pulley is 8 inches out of the path of the vertical line from the periphery of the drum.

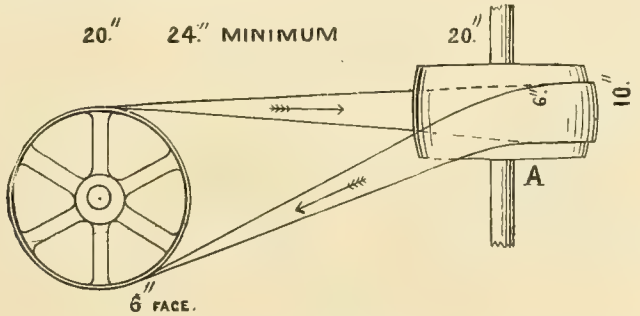


FIG. 100.—QUARTER TWIST BELT.

Figure 100 shows the proper arrangement of a quarter twist belt, where two shafts are at right angles with each other and not in the same plane, and

no tightener is desired. The distance between the near faces of the pulleys must not be less than four times the belt width, and the plane passing through the centre of the faces of one pulley must be tangent to that part of the faces of the other from which the belt is running. The pulley A, from which the belt deflects, should be wider than B, by 5 to 3, and should have extra crown.

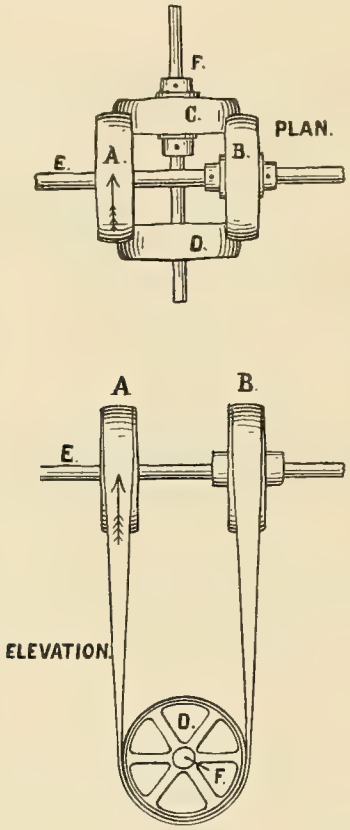


FIG. 101.

Carrying Power around a Corner by a Belt.—In Figure 101 E is the driving shaft, with tight pulley A and loose pulley B; F the driving shaft with tight pulley D and loose pulley C. The pulleys are arranged in a

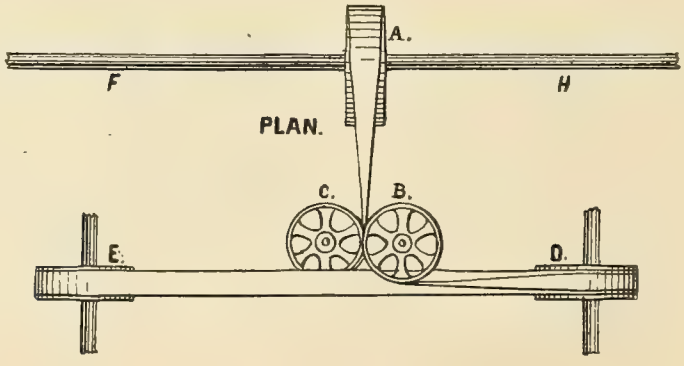


FIG. 102.

square on the plan, having for its side the diameter of the pulleys on the centre of the face. The belt is endless and runs in the direction of the arrow. The loose pulleys B C run in different directions from the shafts

which carry them, but they carry the slack fold of the belt and are relieved of heavy strain on the shafts. This is good for wide belts, with shafts ten belt widths apart, and is very good for carrying power around a corner by a belt.

In Figures 102 and 103, the driving face of the belt is changed between the pulleys D and E. This may be avoided by giving the belt a half twist,

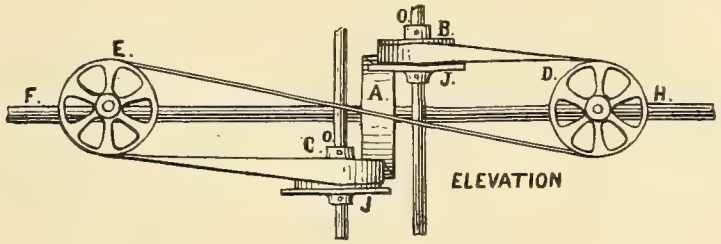


FIG. 103.

but at the expense of injuring the belt more than by using both sides. Collars (O O) are placed over the pulleys B C, and there are stationary flanges (D N) on the uprights under the pulleys. These turn the belts back on the pulley faces, instead of tending to lift and turn belts over, as in the case of flanges fast to pulleys.

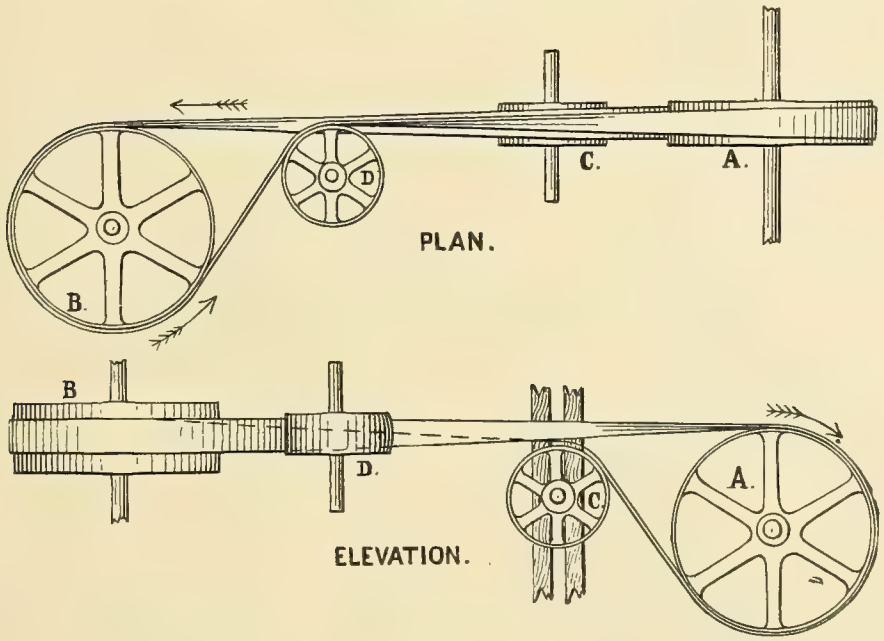
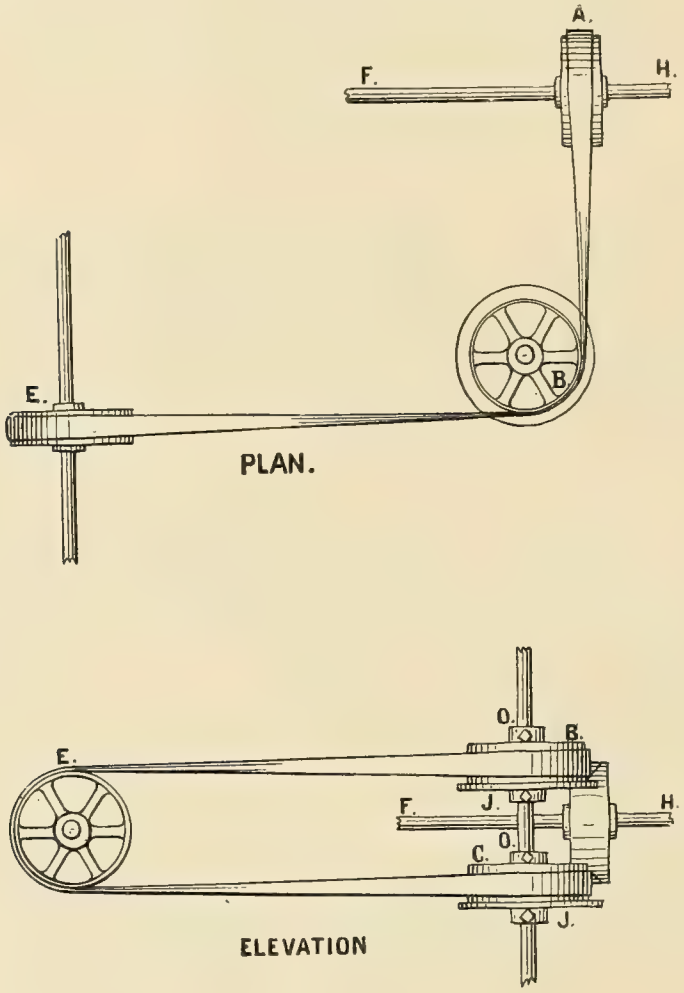


FIG. 104.

In Figure 104, A is the horizontal main line shaft, B the driven pulley on a mill spindle or upright shaft, C a tightener on a shaft parallel to the main shaft, with bearings, in a frame which can be raised or lowered with the pulley when the pulley B is to be stopped or started. D is a guide pulley in fixed bearings. This plan may be used when the pulley A cannot be placed on the main line shaft so as to receive the belt directly from B, as in Figure 103.

In Figures 105 and 106 is shown a very common method of carrying power from a shaft to others at right angles with it. A is the driving pulley on the main shaft F H; D and E driven pulleys on the counters at right angles to the main shaft. There are two upright shafts each with a loose pulley having its face opposite the middle of the face of A, one to the right and the other to the left, over which the belt is passed as shown. The belt will run either way.

Figure 107 illustrates a very difficult case to treat. The shafts are not in the same plane, the pulleys may differ greatly in diameter, the shafts be at



FIGS. 105 AND 106.

any angle with each other, and the belt crossed. This is done by guide pulleys. The vertical cylinder staff A is secured to the flange J and held by a brace G to an overhead timber H. Upon this staff there are two hubs, held by set screws in any position, and each with a flat face to which a flanged bracket, C, is bolted. The upper bolt D serves as an axis about which the break can turn on the lower bolt E, and the slot permits the turning and holds the break at the inclination required by the belt. In the centre of the flange C there is a pin I, upon which the pulleys turn.

In Figure 108 the shafts are at right angles but not in the same plane.

A is the driver on the horizontal shaft; B the driven pulley on the mill spindle, C the tightener or guide pulley, placed at the proper angle for receiving the belt from B and delivering it to A. It has a short shaft running in bear-

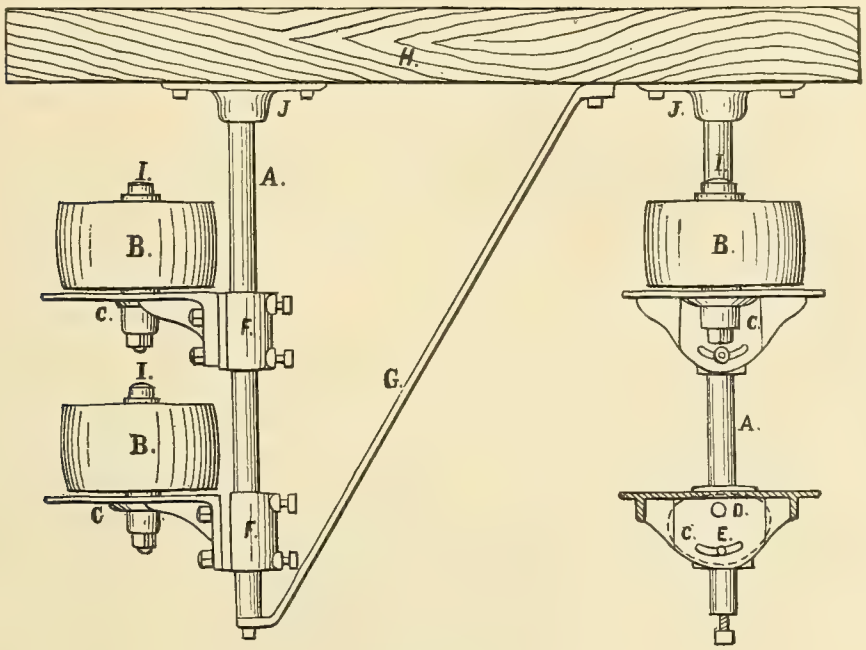


Fig. 107.

ings secured to a frame sliding in fixed grooves, and may be raised to tighten the belt. B has a wide and straight face to allow the stone to be raised and lowered, and to allow of lead of the belt by reason of the different positions

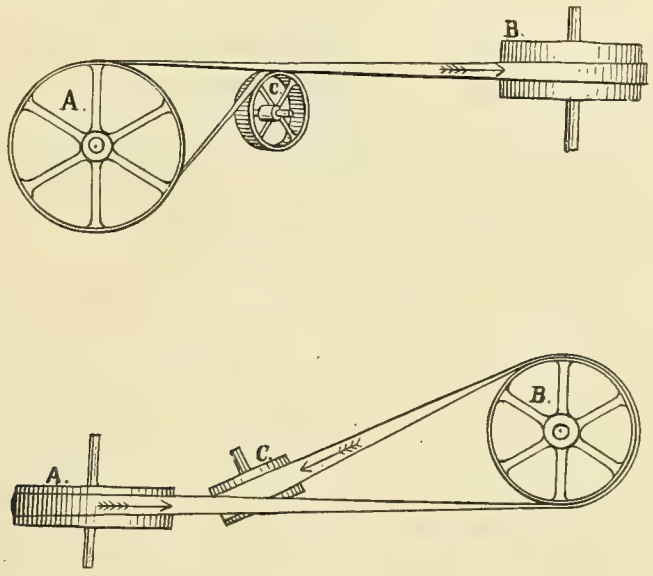


Fig. 108.

of C. A and C should be rounded on their faces. By this arrangement there may be very short distances between the driving and driven shafts.

Shifter.—A good belt shifter and brake for fast running machinery is made by having the fast pulley solid or with one flat side, against which the same bell-crank lever which throws off the belt presses a wooden brake-block.

CHAPTER XIII.

TRANSMISSION BY CHAINS.

Detachable Link Chain.

Detachable Link Chain.—The use of the Ewart detachable drive-chain has become general in many lines of manufacture, and it is daily being employed to a greater extent in mills and elevators. It is a positive transmitting agent, the links being open rectangles as shown in Fig. 109, and the wheels on which it runs being provided with teeth that enter the links, slipping is impossible. The chain is durable and light considering its strength, and can be taken apart or repaired without the use of tools, but cannot detach when in a working position ; it will withstand exposure better than any other wrapping connector known to us, and may be run in water or any chemical solution that is not especially destructive to iron.

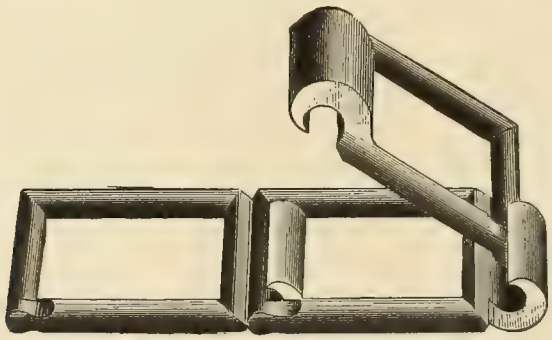


FIG. 109.—METHOD OF COUPLING LINKS TOGETHER.

The links are made of malleable iron, and after being coupled in the chain are tested by a machine designed for the purpose, and which is found to detect defects that would otherwise render the use of chains uncertain.

To obtain the best results with the detachable drive-chain it is well to keep the chain as taut as possible to prevent side-swaying, and to use oil on the joints if the chain is exposed to the weather ; if the use is inside of the mill or elevator no oil is required, as the dust of the grain is a good lubricant in itself. As the range of sizes of the Ewart chain is quite extensive, there being forty, varying in tensile strength from 75 lbs. to 30,000 lbs., it is hardly possible for a problem to be presented that cannot be solved satisfactorily, except where the speed is high and the side room limited. When the Ewart chain is employed to carry elevator buckets special links are inserted in the chain at required intervals, and the cups are either bolted or riveted thereto. The speed and distances between the buckets may be

the same as when leather or rubber belts are used. The chain has certain advantages as compared with belting; it does not require the tension, is cheaper, and as a rule more durable—it can be lengthened or shortened much more readily.

These chains are made in five styles for conveying and elevating, in six for wheel transmission, and in five for light machinery, such as bolting cloths, purifiers, etc. Each of these, of course, has several kinds of attachments to suit the work it is required to do. Chains for elevating and conveying are shown in Figs. 110, 111, 112, 113, 114 on preceding page.

Detachable link-belts have been in use for many years, in particular situations where the use of flat friction belts would not be permissible; but

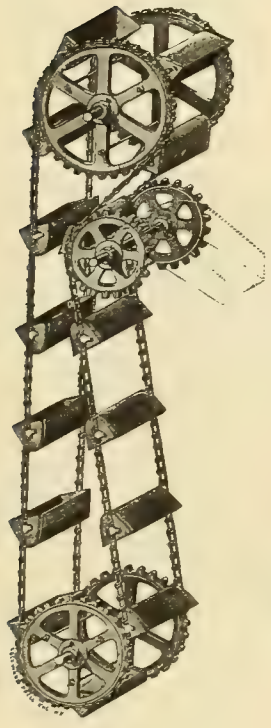


FIG. 110.

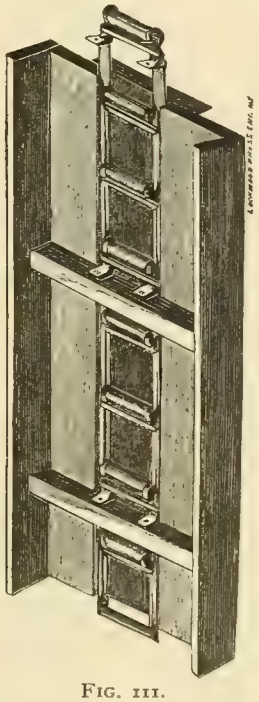


FIG. 111.

FIG. 112.

prior to 1874 these chains had been made rudely and irregularly, and they, together with the wheels on which they ran, were made so largely upon the give-and-take plan, that they were in many respects unsatisfactory, and only used where the use of flat frictional belts of leather, rubber or other materials was impossible. The principal faults of the old-fashioned driving chains were that they were not capable of instant repair without the use of tools, and it was difficult to lengthen or shorten them to suit the varying requirements of tension. They used to climb the sprockets and break or jump off. Repairs were not easily made by unskillful hands. The chain which is now made, as invented by Mr. Ewart, is intended to serve the requirements of those who wish wrapping connectors that will stand exposure to rain, heat, cold or chemicals, that will run in water and in vats containing almost all conceivable wet materials, as well as for ordinary vertical or inclined trans-

mission. The ordinary chains formerly used for driving, ran between sprocket wheels, having V grooves with curved depressions corresponding somewhat to the shape and size of the links as first made, but the elongation of the links very soon made the contact imperfect and unsatisfactory. The flat link chain, working on toothed sprocket wheels was an advance over the ordinary chains running in V grooves, the toothed sprocket being more sure to catch in the open space in the link and produce a positive transmission. But the faults before mentioned, that the chains were difficult to repair, and so on, were a great obstacle to the use of these flat link-chains, except where no other transmission could be employed. As at present made the

FIG. 113.

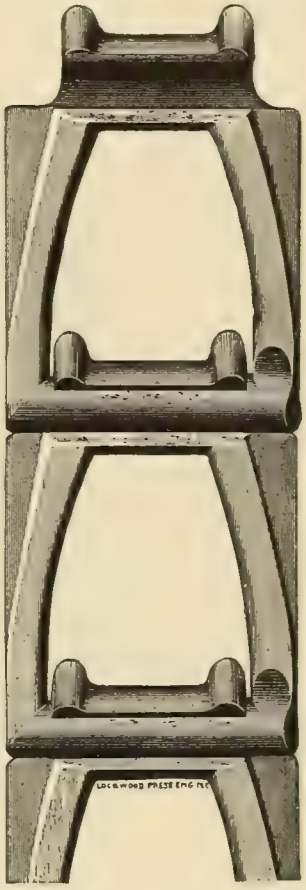


FIG. 114.

chains consist of square malleable iron links having a coupling hook by which these links can be quickly formed into a chain of any length, the links being easily detachable by unskilled hands, so that if it be necessary to take out a link in order to shorten the chain, or to insert a new link in place of one broken, the operation is easy and rapid, and the job an effective one. The cuts show various sizes and styles of these links as used in milling and for grain cleaning.

The attachments to the chains are for the purpose of enabling sweeps, elevator cups, etc., to be fastened to the chain at any portion of its length. A number of them are shown in Figs. 115, 116, 117, 118, 119.

"A" attachments are used to secure the ends of slats for carriers and conveyors. "C" attachments are used for scrapers. "E" attachments are used to

carry elevator cups, two strands of chains being employed. "F" attachments are employed in single strands of chain. "K" attachments are for use on elevators, and for single strand flat conveyors in the same way as the "F" attachments are used.

The chains should always run with the back of the coupling hook to the wheel, the driving sprockets striking upon the outer end of the hook. This leaves the links free to bend at the couplings as they pass on and off the wheels. Long links require larger wheels than shorter ones. With small wheels short links are preferable. The elongation of these chains is slight; the makers state that the elongation per 100 feet for average work amounts to only three-eighths of an inch per foot as a maximum at the end of a year. Tighteners are seldom employed; if desired, a roller of hard wood is sufficient. The weight of the chain itself acts as a tightener more thoroughly than in the case of light friction belts. For this reason the chains can be used in shorter lengths than friction belts, as the tension need not be so great. In fact the chains will run with as much slack as a belt would have if thrown from one pulley and hanging on the shaft. For vertical transmission there is no difficulty, as the removal of a link or two will make up for any wear. For vertical elevation of grains a lineal speed of about 350 feet per minute is

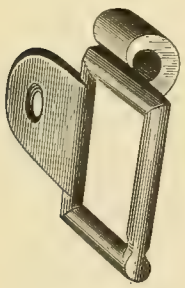


FIG. 115.

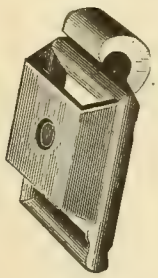


FIG. 116.

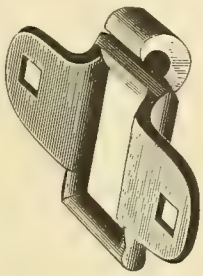


FIG. 117.

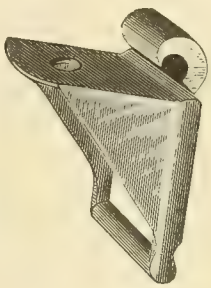


FIG. 118.

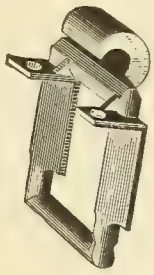


FIG. 119.

found to be the best. The chain elevator cups can wade through the material in the boot, and fill better than in the case of the frictional belt elevators. Cups are attached by bolts or rivets to the attachment links, which are inserted in the chain at whatever distance is desirable for the purpose.

For lubricating the sprockets and links heavy oils are recommended if any are used. Blacklead and grease answer admirably. Of course, no lubricant is needed, and none should be used for running in grain or in flour.

This chain is not exempt from breakage from foreign substances, such as crowbars or stones getting into the machinery and causing sudden stoppage. The sprocket wheel should have a diameter of not less than three times nor more than sixteen times the length of the link. For elevators, one great advantage of positive driven link-belts, is that they can be driven from the bottom as well as the top, and that they can be run slowly to pick up coarse or wet materials. Chain wheels are very convenient in driving conveyors.

There are cases where the link-belt, put up by persons not having full knowledge and experience, has given trouble by reason of the links stretching, so that while the whole belt could be kept the right length by taking out a link from time to time as it became necessary, the pitch of the links became, by this stretching, too great for the pitch of the sprocket wheels on which the chains ran; in such cases the trouble is because the chain or belt is too light.

CHAPTER XIV.

TRANSMISSION BY GEARING.

Gearing — Loss of Power through Gears — Laying out Gear Teeth — Mortise Gearing — Laying out the Teeth of Mortise Wheels — Gear Wheels.

Gearing.—Gear wheels are a positive method of transmitting rotary motion. They have the disadvantage that they are noisy and heavy, and hardly adapted to very high speeds ; and the advantage that they have no slip, and hence transmit rotation without loss of speed. They lose some power by friction—the amount depending upon the design of the teeth and upon the accuracy with which they are made. Cut gears, or those in which the teeth are formed by steel cutters, are better, even if of the same proportion and outline than cast gears made from ordinary patterns. This is because of the greater regularity of the teeth. But cut gears wear faster than those in which the "skin" or outer surface of the casting is not removed. For large cut gears the best are those made by a molding machine, such as is employed by Poole & Hunt, Baltimore. In this system of manufacture one or two teeth are accurately cut as a pattern, which is used on the end of a radius bar in connection with an index circle, which causes the spacing to be perfectly accurate, one tooth of the mold being formed at a time. The expense of making the small pattern of one to three teeth is but slight, and large wheels so molded are cheaper and last longer than cut gears, while more accurate than ordinary cast gears.

Loss of Power through Gears.—"Where the diameters of the gears at the pitch line are eight times that of the journal, the loss by transmission is reckoned at $1\frac{1}{2}$ per cent. for the driver, $1\frac{1}{2}$ per cent. for the driven, and $1\frac{1}{2}$ per cent. for the teeth, making $4\frac{1}{2}$ per cent. With pitch circles only four times the diameter of the bearings the loss of power is 9 per cent. The quarter-turn belt, when used with the tightener, takes a different arrangement or pulley position from that where there is no idler."

Because a gear wheel contains a great quantity of cast iron, it not necessarily strong ; a wheel is only strong when properly proportioned throughout, the metal being concentrated in those points where it is needed. Every pound of unnecessary metal put in gearing is not only an extra expense, but necessitates heavier parts throughout the entire transmission.

Laying out Gear Teeth.—For the practical formation of gear wheels, any two of which having the same pitch will gear together, the author prefers the method described in the *Journal of the Franklin Institute* for January, 1882.

An odontograph can be based on the fact that if the teeth of a rack have

their face and flanks *congruent*, and meeting tangentially in the pitch line, all gear wheels correctly gearing with this rack will correctly gear with each other.

To apply this: To a bar A, Fig. 120, representing a rack, attach a zinc template T, of a tooth, each side consisting of two equal curves meeting in the pitch line. Leave a space, S, between the bar and that part of the template representing the tooth. Make a portion of a disk of the same curve as the gear wheel desired; fasten to it a piece of zinc, *t*. Roll the disc B on

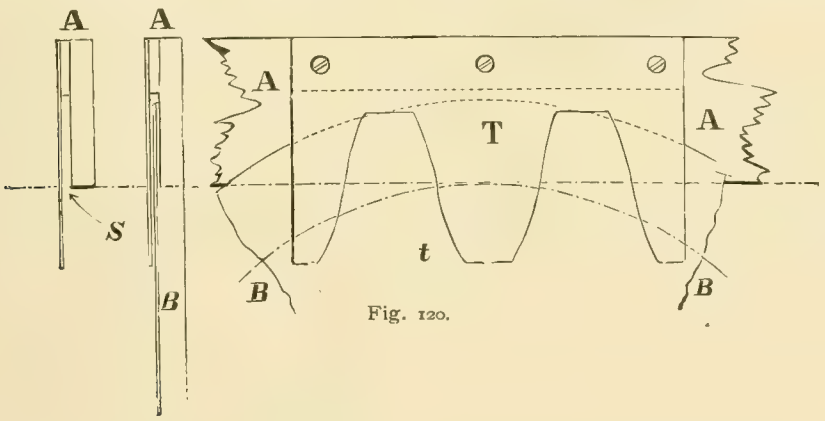


Fig. 120.

the bar A, and scribe the tooth T in a number of positions on the template sheet *t* (Fig. 121).

To prevent slip, use a watch-spring or strip of zinc, one end fastened to the rack, the other to the wheel plate. Cut and file the second template *t*—which ought to reach to the centre of the plate B—and have a fine centre hole there punched.

For epicycloid teeth the original template must be two cycloids, developed

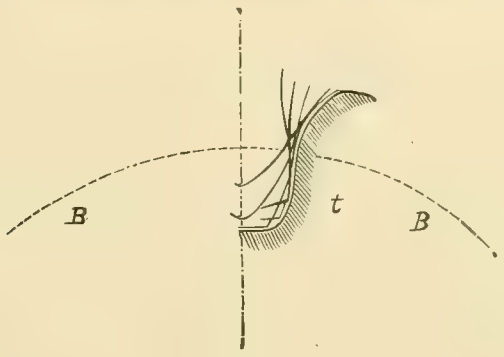


Fig. 121.

by rolling on the rack, a circle with the diameter of the pitch radius of the smallest pinion likely to be required. For involute teeth, the rack sides should have an angle of $75\frac{3}{4}°$. For bevel wheels the curve had best be cycloid, with draft near the pitch line.

Some mechanics (especially watchmakers) give the driving-wheel teeth greater height above the pitch line than the driver.

Mortise Gearing.—Mortise wheels cost a trifle more than iron ones, but make much less noise. For making the cogs, hornbeam, hickory, maple,

or sugar-maple wood is used. Only the butt ends of the toughest trees should be taken, and the wood should have been seasoned three to five years. Defective pieces should be excluded. Wooden cogs do away with all of the noise and clatter of iron wheels; they wear away when working with iron ones, and there will be formed a shoulder which should be cut off from time to time. They should be kept greased with tallow. They cannot be so well made by hand that the action will be uniform on all points of contact. Nothing but a rotary machine cutter can accomplish this result.

Wood and iron gears work better together than wood together or iron together. Wooden cogs should be about three times as thick as iron ones, though some say that an iron cog stands in the proportion of five to three in transmitting power, when compared with wooden ones. To order wooden cogs, take one out of the wheel, measure it in all its dimensions, and send with the order sketches like the accompanying Figure 120.

Laying Out the Teeth of Mortise Wheels.—"The cogs being fixed in the rim of the pattern wheel much larger than they are intended to

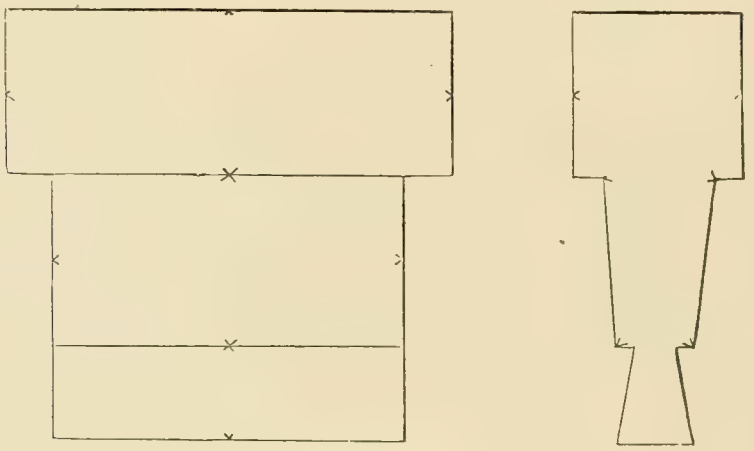


FIG. 122.—MEASUREMENTS FOR COGS.

be, the circle or pitch line is described around the face of the rough cogs, another circle is described within the pitch circle for the bottom of the teeth, and a third without it for the extremities. After these preparations the pitch circle is accurately divided into the number of parts or teeth which it is intended to make upon the wheel, a pair of compasses are then opened out to the extent of one and a quarter of these divisions, and with this radius arcs or semicircles are struck on each side of every division, from the pitch line to the outward circle. Thus, the point of the compasses being set in the division, the curve on one side of a cog and on one side of another cog are described, then the point of the compass being set on the adjacent division the curve is described. This completes the curved portion of the cogs, and, being done all around, completes every tooth. The remaining portion of the cog within the pitch circle is bounded by two straight lines drawn from the points and toward the centre; this being done also to the cogs all round, the wheel is set out, and the cogs after being dressed or cut down to the lines will be formed ready to work, every cog being of the same breadth, and the

space between every one and its neighbor is exactly equal to the breadth, provided the compasses are opened to the extent of one division and a quarter as first described. The same rule applies to the teeth of beveled wheels formed upon their developed pitch lines.

"The best mathematical and practical plans are thus presented. Mathematicians and millwrights seem to be somewhat at issue on this topic, the former complaining that the 'millwrights have their own nostrums, most of which are egregiously faulty, being little else indeed than instructions how to make teeth clear each other without sticking.' On the other hand, Mr. Buchanan, an excellent practical millwright, observes that 'the method of forming teeth by the arcs of circles will always enable a workman to execute short teeth nearer to the true form than any pattern tooth will enable him to do.' 'Pattern teeth,' he further observes, 'and compound curves are things that may on some occasions be very useful, as where the teeth are long and of considerable magnitude in respect to that of the wheel or pinion to which they belong. But in all ordinary forms of wheel-work, such operations must consume an immense quantity of valuable labor, to attain the same degree of accuracy that is at once obtained by means of circular arcs.' He also states that 'It is the general opinion of those who are in the practice of constructing mill-work, that teeth ought, if possible, never to begin to act before they reach the line of centres, as this mode of action is thought to occasion much unnecessary friction, the friction of the receding teeth being less than that of the approaching teeth.

"Much time and expense have been bestowed in some places in dressing the teeth of iron wheels with chisels and files, the teeth being cast large in the first instance to be reduced in this way to the proper shape. This method, according to Mr. Tredgold, is now but seldom practised, the outer surface of the iron, which is the hardest and smoothest for wearing, being destroyed by this operation, in addition to the disadvantage in point of economy and labor. The teeth of all wheels should, however, be carefully inspected, and if they are in the least irregular, should be reduced by the file and chisel.

"It is generally recommended, in calculating the number of teeth in two wheels playing into each other, to make one odd tooth, sometimes called by millwrights a hunting cog, that the same teeth may not constantly come together at every revolution or given number of revolutions. This was done originally with the intention of distributing the wear upon wooden cogs more equally, and to obviate any accidental differences in the hardness or solidity of this yielding material. In modern cast-iron wheels the metal is of such uniform hardness that even in match gearing, composed of two wheels of the same size and number of teeth, each one of which must always engage the same tooth at every revolution, no material difference is observed in the wear of any one tooth; on the contrary, it seems that if there be any original inequality in the surfaces or solidity of the teeth, they will sooner become adjusted to each other by their constantly returning mutual attrition at the irregular points of action, and for this very reason are commonly found to run more silently after being worn than almost any other kind of wheel-work constructed with ordinary accuracy."

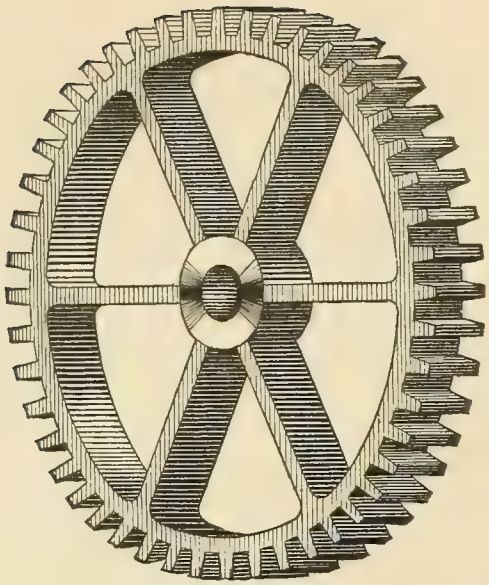


FIG. 123.—SOLID SPUR.

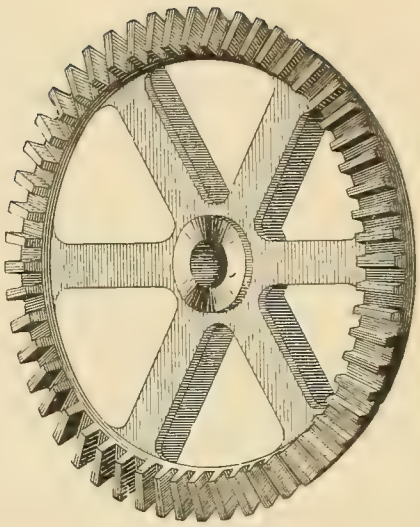


FIG. 127.—SOLID MITRE.

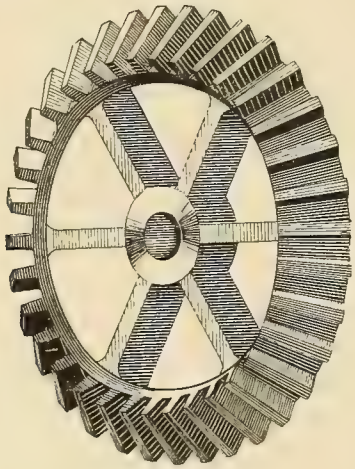


FIG. 124.—SOLID MITRE.

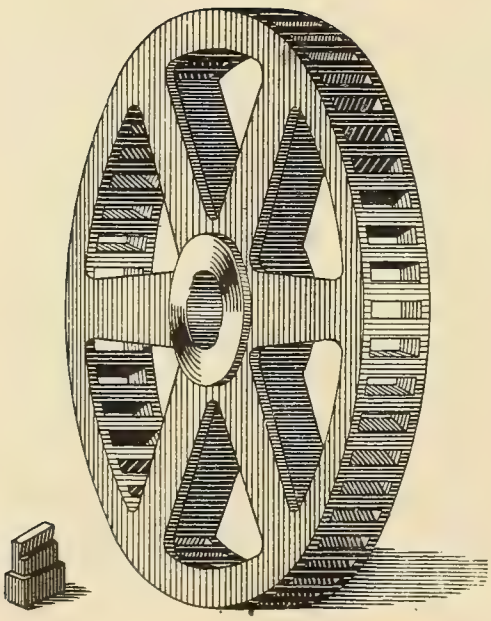


FIG. 125.—SPUR SHELL.

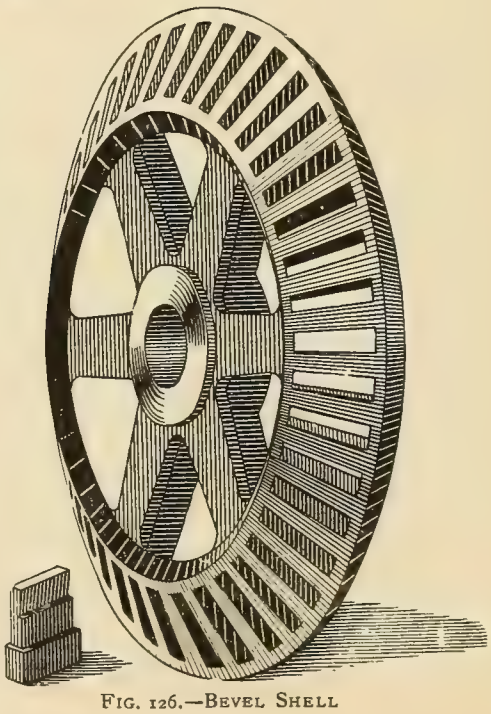


FIG. 126.—BEVEL SHELL

Figure 123 is a wide-faced spur wheel. Figure 124 is a strong form of bevel wheel. Figure 125 shows the shell of a mortise wheel, with a cog lying beside it. Figure 126 is a bevel shell. Figure 127 is a bevel wheel very nearly approaching a crown wheel.

Gear Wheels.—Gear wheels are used, *First*, to transmit the rotation from one shaft to another at a short distance. Where these shafts are parallel the gears are called "spur gears." Where they are at an angle they are usually conical, crown or bevel gears. *Second*, To transmit motion from a rotating shaft to a rectilineal motion to a plain toothed surface. With this class the millwright has but little to do, as this form occurs in very few places, except in belt-tightening pulleys, and the gate of the flume in a water-driven mill. *Third*, To transmit rotation from one shaft to another where they are in planes perpendicular to each other.

It is always necessary to have a certain velocity ratio, this being obtained by two conditions which depend one upon another: the diameter of the wheels and the number of their teeth.

To find the diameters we must have the distance between the axes and the relations of the velocities. The radii of the pitch circles must together be equal to the distance between the centres of the axes, and the radii must be in inverse proportion to the velocities (the numbers of teeth depending upon the radii). Where there is very great velocity ratio, we must employ more than two wheels to effect the change of speed or transmission of motion. Sometimes, for convenience in driving various lines of machinery, a velocity ratio which might be got by two wheels is obtained by several.

There are eight elements in the construction of teeth: thickness, space, distance, tooth-depth, number of teeth, depth of face, depth of shoulder, form of tooth and total depth.

THICKNESS.—The thickness depends upon the force that they have to transmit and the material of which they are made. We must consider the maximum amount of force to be transmitted, and suppose it all to go upon one corner of one tooth. If the tooth were made of mathematical precision, and could be so maintained, the space at the pitch line should be exactly equal to the thickness of the tooth. In practice it is found necessary to allow at least $\frac{1}{15}$ the thickness of a tooth as "play." In the most favorable cases, where the tooth is cast, the space should be $\frac{1}{10}$ the thickness.

DISTANCE.—The distance between two teeth must be equal to the thickness plus the space. It must be the same upon both wheels that gear together, and must be contained an exact number of times in the circumference of the pitch circle.

SHOULDER.—The shoulder is that part between the pitch circle and the base of the tooth. It is sometimes called the flank. Only the shoulder or flank should come in contact with the face of the tooth of the other wheel. Teeth must be deep enough to allow at least two teeth of each wheel to be in motion at a time. Pinions should not have less than 15 teeth. Where a wooden wheel meshes with an iron pinion, the wooden wheel has thicker

teeth than the pinion, and hence the spaces on the pinion are greater than those on the wheel, yet the distance between the two centres must be the same on the two wheels.

Breadth.—The greater the breadth the greater the strength of the gear. Where the gear is very wide, it is best to have the teeth divided in two parts laterally, the teeth in these two sections alternating with one another—the teeth in one section opposite the space in another. This gives smoother action. This is especially good for mortise wheels, giving a strong core in the middle of the wheel between the two mortised sections. Epicycloid gears will drive wheels of only one diameter, unless the generating circle has as diameter the

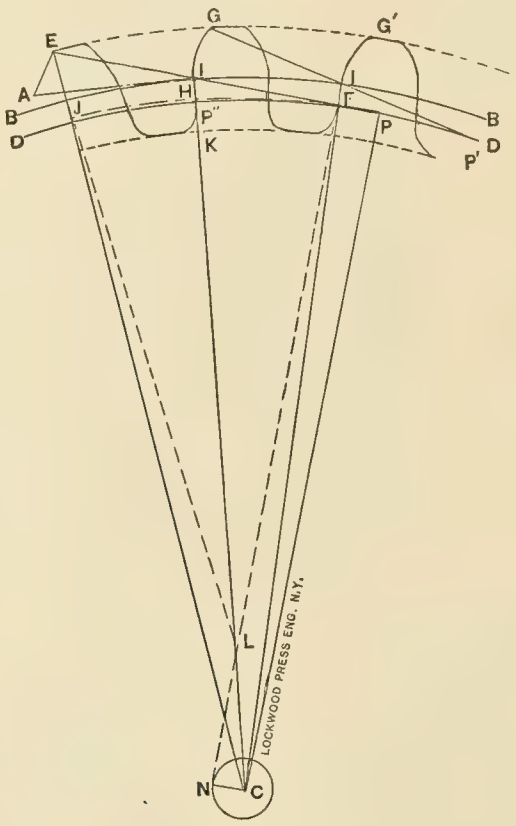


Fig. 128.—Involute Gears.

radius of the smallest pinion, and is made to roll successively upon the pitch circles of all the wheels that are to mesh together.

Involute Gears.—The involute has a curve generated by the motion of one point of a tangent rolled about a circle. This kind of tooth works with wheels of several different diameters, and with wheels which have been thrust out of correct position of absolute contact of pitch circles.

The thickness of the ring which carries the tooth of a cast-iron wheel should be equal to the thickness of the root of the tooth. This last thickness may be obtained by dividing the greatest pressure to be exerted between a pair of cast-iron teeth in pounds by 1,500 ; the square root of the product will be the least possible thickness in inches.

The least breadth may be got by dividing the greatest pressure in pounds by the pitch in inches and by 160; the quotient will be the breadth in inches. The path of contact of the tooth should be a straight line coinciding with the line of connection, making a constant angle with the line of centres, and inclined at an angle of $14\frac{1}{4}°$ to the common tangent of the pitch lines.

Referring to the cut, Fig. 128, let, *First*, C represent the centre of the wheel, I the pitch point, C I the radius, B I B the pitch circle. We will suppose we are going to draw a wheel of 30 teeth. To draw the base circle and line of connection, take a radius, C P, equal to $\frac{6}{6}\frac{3}{5}$ of C I; with this, draw the base circle D P D with radius I P, equal to $\frac{1}{6}\frac{6}{5}$, the pitch radius, Draw a short circular arch centred in I, and cutting the base circle in P, draw the straight line P F I E, which is the line of connection.

Second, To find the normal pitch, the addendum and the real radius, and to draw the addendum circle and the flank circle. From the pitch point I draw a straight line, I A, tangent to the pitch circle. From A let fall A E perpendicular to I E, then I E will be the normal pitch along the line of connection, or the distance from the front of one tooth to the front of the next; or what is the same thing, the pitch or distance between tooth centres.

This normal pitch will be in the same proportion to the circular pitch as the radius of the face circle is to the radius of the pitch circle; that is, I E divided by I A equals C P divided by C I $= \frac{6}{6}\frac{3}{5}$.

To insure that at least two pairs of teeth shall always mesh, the arc of contact may consist of two halves, each equal to the pitch. Lay off on the line of connection, E P, the distance I F equal to I E, then E F will be the path of contact. A straight line from C to E will be the real radius. The circle E G G, with that radius, will be the addendum circle which the tops of all the teeth must touch. With the radius C F draw the circle F H. This may be called the flank circle, because it marks the inner ends of the flanks of all of the teeth. C E less C I is the addendum.

To draw the root circle which the bottoms of all the tooth spaces are to touch, first find the greatest addendum of any wheel with which that wheel may have to gear. This will be the addendum of the smallest pinion of the same pitch and obliquity. With an obliquity of $14\frac{1}{4}°$ that pinion has 25 teeth. To find the addendum of this pinion of 25 teeth through them parallel to P C, draw F L, cutting I C in L, join L E; the required greatest addendum will be L E minus L I, which is very nearly .343 of the pitch. Generally .35 of the pitch is used for addendum. To this greatest addendum make suitable lines for clearance, and lay off the source, I K, inward from the pitch circle along the radius. C K will be theradius of the root circle.

To draw the tooth traces, mark the pitch point of the tooth front, I I′, &c., and those of their backs, by laying off a suitable thickness on the pitch circle. Shape the templet accurately to the figure of the base circle. File a piece of watch-spring so as to leave a pair of projecting tracing points from its edges. Drill a round hole in one end of the spring and fix it to the middle of the templet edge by a screw or thumb tack. Put the templet on the drawing or

pattern so as to coincide with the base circle, and so that the lower end of the tracing point shall pass through the pitch point of the tooth, then that tracing point will draw the front of the tooth. To trace the backs of the teeth, turn the spring over on the templet. The distance from the screw to the tracing point should not be less than twice the normal pitch.

The clearing curves are the trace of the holes inside the flank circle of each. Their sides should be tangent to the inner ends of the flanks, and their bottoms should coincide with the root circle.

The back lash also of involute teeth is variable at will. It can be increased by moving the wheels farther apart, and diminished by bringing them closer together, care being taken not to let them jam.

CHAPTER XV.

TRANSMISSION—PULLEYS.

Pulleys—Stepped Pulleys—Split Pulleys—Loose Pulleys—Idle Pulleys—Tractive Force—Lagging—Bevel and Mitre Friction Pulleys.

Pulleys.—Pulleys for flat belts may be of cast iron, wrought iron, or wood; and may have their faces either plain or covered with a lagging composed of leather, rubber or paper.

The lighter a pulley is, the less it ought to cost, the less the freight bill on it, and the less sagging weight there will be upon the shaft. There is a certain way of putting metal in a cast-iron pulley which will make it light, stiff, and strong. There are some establishments which make pulleys notoriously heavy, and others which make them as notoriously light. There is between these two customs what the Irishman calls the "middle ixtrame," in which every pound of metal is put in a certain place with an intelligent purpose. Such pulleys may be picked out of a car load by reason of their *great beauty*, because it strangely happens that where metal is properly put in place there is a grace and harmony of outline which is destroyed by any other system of design. The writer has found the pulleys of Poole & Hunt, Baltimore, strong, serviceable, and satisfactory in every way.

Stepped Pulleys.—A millwright often has to ask himself the question: "How can I lay out a cone pulley so that the belts will be of the same tension on all the pulleys?" Now, often he will erroneously make the diameters of the driving and driven shafts the same. For example: he wants to make a cone with the largest pulley on the driving shaft 16 inches, and the smallest cone on the driven shaft 7 inches diameter. These two diameters he adds together, making 23 inches. He now proceeds, desiring to make his next pulley 14 inches. This would make the next pulley on the driven cone 9 inches, and so on.

This reasoning is not correct.

The belts in these pulleys will not be of the same tension on all the steps. In order to thoroughly elucidate this matter, when two cones of pulleys, or "stepped cones," are made alike—that is, with equal steps, such that the sum of the diameters of each belted pair is the same, a *crossed belt* will run with equal tension on any pair so made, when the shafts are parallel and the cones reversed; but an *uncrossed belt* will not so run on such cones. To show why the open belt will not have equal tension on all the pulleys, let AB, in Fig. 131, be two equal stepped cones on parallel axes, AE and BD. Now, if the sum of the diameters of the extreme pulleys E and F be equal to the sum of the diameters of C and D, the connecting strips EF and CD of the belt will be equal, because the enrolled parts are equal by the construction

of the cones; but EF and CD cannot be equal, because they are not parallel, and hence it plainly appears that CD, being at right angles to the shafts, is shorter than EF; therefore, to preserve a certain tension of the belt when on the extreme pulleys, the middle pulleys must be larger than the size given by equal steps, in order to take up this difference. To find the proper diameters of the intermediate pulleys for open belt cones, first get, by Rankine's rule (annexed), the radius NO from the given radii IJ, KL, and distance between shafts, and through the points J O L describe a circle arc, upon which draw the faces of all the pulleys in the series as shown. Make both cones by this rule, and an open belt will run upon them with equal tension. Unequal cones may be made in like manner by drawing two similar cones, and then using, say, S T V of the large end of one, and X Y Z of the small end of the other, as needed to serve the purpose. For wheels driven by round bands in V grooves the same rules apply, observing that the *effective* diameters must be taken at the line of *band contact* in the grooves,

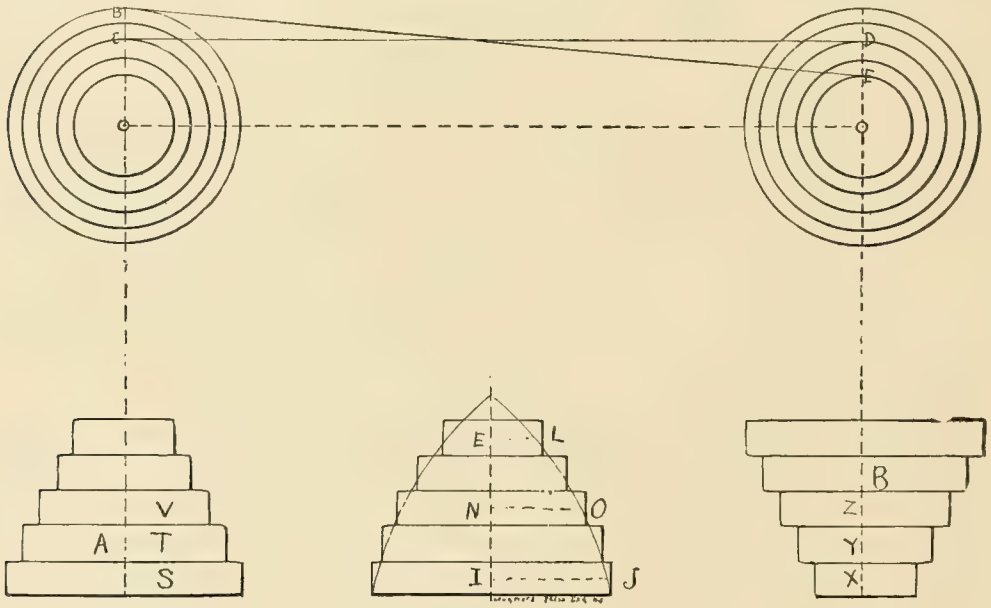


FIG. 129.

which are the acting circles of adhesion. All the grooves must be alike, and should have concave sides, like a Gothic arch, instead of straight, and the band must not touch the bottom of the groove.

Rankine's Rule.—When the belt is uncrossed, use a pair of equal and similar conoids tapering opposite ways, and bulging in the middle, according to the following formula: Let c denote the distance between the axes of the conoids; r_1 the radius of the larger end of each; r_2 the radius of the smaller end; then the radius in the middle, r_0 is found as follows:

$$r_0 = \frac{r_1 + r_2}{2} + \frac{(r_1 - r_2)^2}{6.28\,c}$$

Split Pulleys.—On this head the writer can hardly do better than to quote from the *American Machinist* the remarks of that humorous and practical classic, "Chordal":

* * * * "My own opinion is that the split pulley is a good institution. Their first cost is a trifle more than a solid pulley, and they are not as hand-

some, but the cost in the end will be found to be less than solid pulleys, and a sort of 'functional beauty' should result from the apparent propriety of the thing.

* * * * "I know that all well regulated machine-shops have excellent intentions of making all pulley changes, etc., at night or at noon, so as not to interfere with work. Such good intentions are like many other good intentions around machine-shops, that is, they don't amount to much. There is hardly a shop in the land which don't stop in the middle of a day's work, time after time during the year, to do some fussing with line-shaft pulleys.

* * * * "If a twenty-inch pulley has to be put on a shaft in a small shop working, say, ten men, the whole thing don't hesitate to come to a standstill while the change is being made. Every man, from proprietor down to cub, is under the impression that he is doing something on the job himself, and, as a consequence, the job must be charged with the total machine-shop labor and expense bill for about five hours. The more men there are, the longer it takes to do the work.

"It looks like a short and simple piece of work to stop a line shaft, unbolt couplings, loosen collars, move part of the shaft endwise, worry one of the couplings off, get three or four pulleys off, put the new pulley on, put the old ones back, worry the coupling on again, move the shaft back, put in the coupling bolts, tighten up collars and pulley screws, and start the machine again. It's mighty easy and cheap to tell about it, but it takes a long time, and it costs lots of money.

* * * * "In the first place, something has to be cobbled up to stand on. Who ever saw a nice line-shaft trestle around a shop? Then it is found that the coupling nuts are let into counter-seats, and that a special wrench must be had. Question:—'Shall we wait for a wrench to be forged, or shall we get the nuts off with a chisel?' Answer by all:—'O! get a good wrench made.' The wrench is ordered, and while it is being made every last one of the nuts is hogged off with a chisel. You might naturally think that this wrench would now be laid away for future use on this same shaft job. There's where a mistake comes in. The wrench, so nicely laid away, cannot be found the next time this shaft is tinkered with, and if it was found it would have no effect upon these nuts which have been foliated with a cold chisel.

"When the nuts are off it is found that the smart genius who fitted up the coupling labored under the impression that the bolts ought to fit the holes—driven in oil, you know. They were driven in oil. If they had not been they never could have been driven at all. The job now is to drive them out in oil. While one man goes for a chunk of copper, the man who ordered the copper proceeds to batter them out with his hammer.

"The bolts are finally out and the shaft backed open a foot or so, after about a dozen interfering pulleys are hunted out and loosened. The next thing is to unkey the coupling. It is the case of the wrench over again. While the blacksmith is forging a special drift the head man is pecking at the key with every old drift and chisel around the place, and gets the small end of the key so battered up that when the special drift is done there is a double quantity of work for it to do. When the key comes out the coupling has to be

hammered off. Blocks of wood and pieces of copper are talked about, but some one discovers old hammer marks on the coupling, and this is taken as a license to pound it all to pieces.

"By the time the coupling comes off, two or three pulleys have been cracked or broken by awkward back strokes. After the coupling is off the real work is done in two minutes. Five or six pulleys are slipped off, the new one slipped on, and the old ones replaced. I say the old pulleys are slipped off, but two or three in the lot will be found so tight that they will have to be slipped off with a sledge. The scientific pounding on the coupling dented the shaft some, and no one ever thinks of filing a dent out of a shaft till he has tried to drive something past it.

"The entire process is now reversed, the coupling driven on, the old key searched for and not found, a new one ordered, the old one found in the meantime, the old one found to be so battered up as to be useless, all hands wait for the new one, head man gets tired waiting and concludes to sock the old ones in, does so, shaft pried into place, two bolts put in, two bolts found so battered up as to require a thread to be filed on them and the upset filed out of them, and at last the job is complete and the boys go to "work" again.

"Total cost of putting on new pulley—cost of pulley, plus four hours' total expenses and labor of a small machine shop, plus four hours' idleness of a small machine shop. Total equals cost of half a dozen split pulleys.

* * * * "The description I have given of this job only applies if the job happens to be a lucky one. Generally the shop comes to a standstill about an hour after the job is done; some big belt to be put on. After a while another stoppage; forgot to tighten some pulley. Another stoppage; a pulley is set two inches out of place.

"Next day there is half a stoppage. Part of the shaft stops and part keeps on. Some slip collar was left loose, and some loose coupling crawled right off of the shaft. This is easily fixed and is made an excuse for tightening all set-screws which have been loosened. The next day the real snarl comes. It is found that in replacing the old pulleys one of them got put on in the wrong place. There is no way out of this but to go through the whole job again, The only reason the second doing of the job is not as laborious as the first is that the fits are all fresh.

* * * * "Split pulleys are easily and cheaply put in place. Thirty minutes will generally do for placing one. The shaft is not marred by set-screws or other such fastenings. The couplings become simply an expedient to save making a shaft in one length."

Split pulleys or couplings should have the hole bored a trifle larger than the shaft. The bolts will bring it to a perfect bearing. If bored too small the hole will only fit the shaft in two places. A slight grip all around is better than a tight grip at two points only. It is claimed for wrought-iron split pulleys that they are lighter, stronger and more rigid than cast. The arms and rim are made of wrought iron, and the arms are so twisted at their connection with the rim that the wide part of the iron stands in the direction of the strain, while presenting the minimum of resistance to the atmosphere in revolution. They are easy to fix on the shaft, being made in halves.

Neither the shafting nor the pulleys need be disturbed to attach them or remove them at any point. They are claimed to give increased grip between the belt and the pulley, and transmit more power for a given diameter. The writer's tests prove otherwise. For exportation they should be very advantageous by reason of their lightness and strength, and the small space they occupy when apart, by reason of their being in halves. They can be made to any size, either round or flat on their face. Where split pulleys are used, the bolted portions should be put together by bolts stout enough to make them as strong as any other part of the pulley.

Loose Pulleys.—Loose pulleys require constant attention and much oil, and are very hard on the belt. It is best to have them a trifle smaller than the tight pulley, and with a step or flange running up to the diameter of the tight one. This takes the strain off the belt and the friction from the pulleys.

Idle Pulleys.—As a general rule, idle pulleys (not tighteners nor loose pulleys) are an excuse for bad engineering. But there are cases where it is absolutely necessary to carry a belt under a timber, or else to cut away the timber, and the latter might be expensive for several reasons besides weakening the building. Sometimes where there is a very long belt an idler is used to steady the slack side, or where the belt comes too near the floor, to hold it up.

Tractive Force.—The grip or driving tension of leather belts upon smooth turned cast-iron pulleys, was ascertained by Robert Briggs and H. R. Towne, to be 67 pounds per inch of width of the belt. This is about one-third of the known breaking strength of ordinary lacing or other belt joints. With equal arcs of contact the adhesion differs very little on pulleys of 12.24 or 42 inches diameter. The following table gives the net forces which have to be carried over each inch width of single leather, covering various arcs of contact (tension not stated) from $\frac{1}{4}$ to $\frac{3}{4}$ of the circumference.

Arc of Contact.	Lbs. per inch.	Arc of Contact.	Lbs. per inch.
90°	32.33	150°	44.64
100°	34.80	180°	49.00
110°	37.07	210°	52.52
120°	39.18	240°	55.33
135°	42.06	270°	57.58

This table may not always be at hand, but the figures thereof may be approximated by adding 27 to one-seventh the number of degrees of contact. This will give the force in pounds per inch in width of the belt. Of course the number of lineal feet per minute belt speed, when multiplied by this number of pounds strain, will give the foot pounds, from which the horse-power of the belt can be readily ascertained.

In one set of experiments concerning the tractive force of smooth-faced pulleys, two pulleys were made, one of soft maple and the other of iron, both highly finished; each 17 inches in diameter, 6 inches face, and put up as

shown in Fig. 130. There is a double crank, A, with two foot arms, the iron pulley being journaled in its upper end, having bearings 1½ inches diameter, 3 inches long, running in babbitt. The frame is held in trunnions and balanced by the weight B. W and B are weight boxes. The pulley face I, is rather wider than 6 inches, so that it may have a cord C, running in a groove cut around it with the centre of the cord just at the periphery. V is a driving pulley, running watch-wise, or from left to right. The pressure between the pulleys is determined by the weight W. The wooden pulley being set in motion, the other pulley will be rolled and the weight W raised ; the pressure required to raise the weight being noted, then the pressure would be noted which would hold the weight from slipping down. After these tests, the frame was reversed so that the weight in the pressure boxes would tend to separate the pulleys, which were connected by the 6-inch leather belt, and the experiments continued. It was found that the pressure required to raise the weight, and that to raise it without slip, was greater in the case of the belted pulleys than in that of the friction pulleys ; the pressures being with a weight

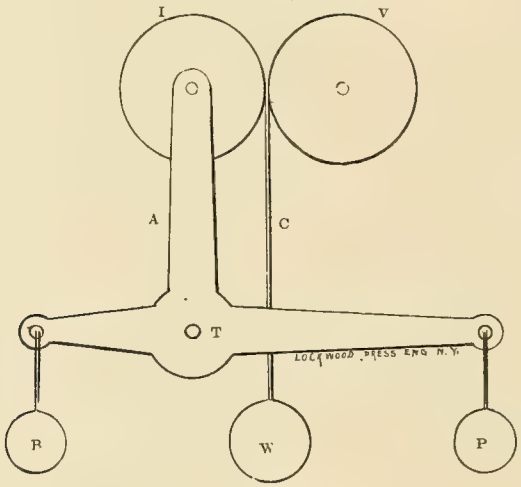


FIG. 130.

of ten pounds raised respectively 29 and 33 pounds on the friction pulleys and 30 and 34 pounds on the belted ; while with 180 pounds raised there were 538 and 561 pounds with the friction pulleys and 592 and 731 with the belted. This shows that the friction wheels had greater traction than the belted pulleys ; and that while the adhesion falls off as the work increases, the friction increases as the labor gets greater. As the work increases, the pressure required to just do the work increases in the case of the belts, while it remains about the same with the friction wheels.

Lagging.—To cover slipping pulleys with leather, take a piece of belt leather of uniform thickness, as wide as the pulley face and as long as the circumference of the pulley plus the required lap and less six per cent. (this six per cent. scantness is to make a tight-stretched fit) ; then scarf and unite the lap so as not to increase the thickness when cemented together, otherwise the belt would drive irregularly. Draw this on by iron hooks, putting hair side out and putting it so that the outer end of the lap will be raised when the covering slips on the pulley. This is to prevent the joint opening and

tearing. Rivet to the pulley rim, sinking the heads below the driving surface. Copper rivets are best. Remember that in adding a leather lagging or covering to a pulley, you are increasing its diameter nearly one-half an inch, which will slightly affect speeds and power. Belts, grain side to the pulley, drive about 50 per cent. more after than before the pulley was covered. Use

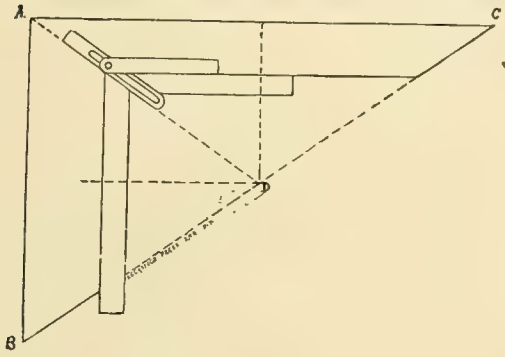


FIG. 131.

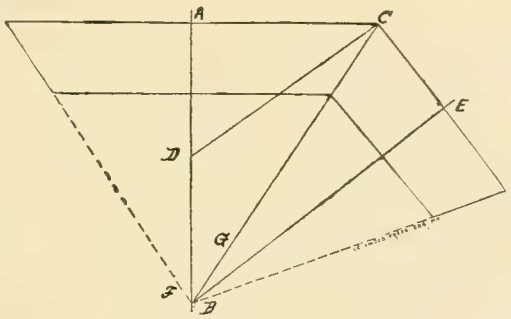


FIG. 132.

a cement of three pounds of glue made up with vinegar, to which is added a teacupful of Venice turpentine. Leather pulley lagging cannot be used in damp places.

Bevel and Mitre Friction Pulleys.—Bevel and mitre friction pulleys work quite well, nearly as well as if cylindrical; having only

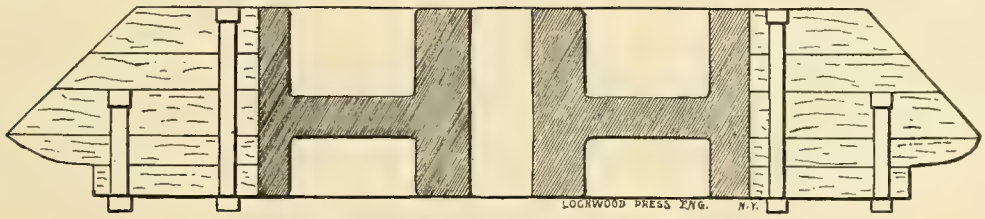


FIG. 133.—WRONG FORM OF BEVEL FRICTION PULLEY.

this disadvantage, that their face cannot be extended very far without increasing the diameter. But for ten horse-power or less the bevel friction is very good, and especially adapted to reversing motion. There is an iron cone, just as for a bevel pinion, except that it has a turned

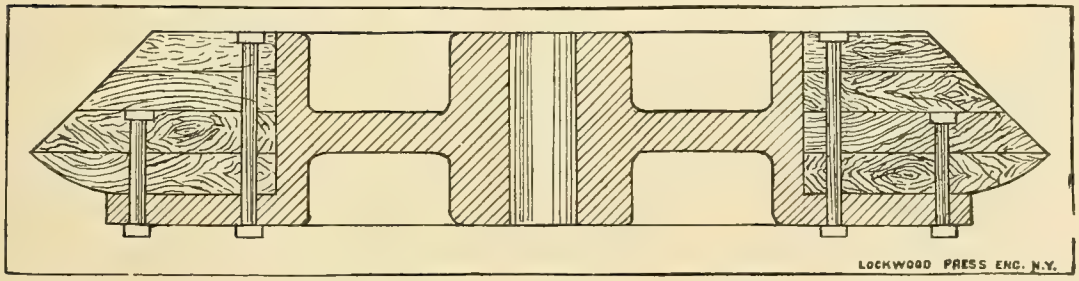


FIG. 134.—RIGHT FORM OF BEVEL FRICTION PULLEY.

face. The rim may be a little lighter than for a pinion. To get the exact diameter and bevel, place a square across the smaller end of the finished iron pulley, and set the bevel to it, as shown in Fig. 131, which

will be the right bevel for the driver. Draw the lines AB, AC, making AB equal to the large diameter of the iron pulley, and the angle A 90°. Then with the square and bevel draw BC and AD. AC will be the diameter required for the driver. The other dimensions are easily obtained. For shafts at acute angles, draw the lines as in Fig. 132. Let AB represent the driving shaft; AC, at a right angle to it, should be as long as half the diameter of the driving pulley. Then draw CD at an angle at which the shafts are to be set; draw CE at right angles to this, as long as half the diameter of the other pulley. From E draw EF parallel to CD, and this will represent the other shaft. From the point of a section of this and the line AB draw GC, which will give the bevels for both pulleys. For pulleys $2\frac{1}{2}$ feet in diameter or less, the driver may be upon hub flange about two-thirds the pulley diameter. Instead of this being made with a cast-iron core as shown in Fig. 133, there should be a hub flange along the lower side, to which the thickness of wood should be bolted (Fig. 134). The form of iron centre shown in Fig. 133 is a common one, but a very bad one.

CHAPTER XVI.

ROPE TRANSMISSION.

Location of Power — Transmission of Power by Wire Ropes — Distance of Transmission — Driving Ropes — Sheaves for Wire Rope — Deflection of Ropes — Long Transmissions — Rope Connecting Rods.

Rope transmission permits placing a water-power and mill up on a bank out of the reach of freshets—a most important consideration—and also allows the mill to be placed convenient to roads, etc., while the water-wheel may be placed to best advantage.

Transmission of Power by Wire Ropes.—The distance to which this can be applied ranges from fifty to sixty feet up to about three miles. It commences at a point where a belt becomes too long to be used profitably, and can thence be extended almost indefinitely. The power can be conveyed up an ascent of 1 in 8 or 10, or down a moderate slope as well.

A table of horse-powers is given on following page. It embraces every case that will ordinarily arise in practice, and one can readily select that combination which will suit his own case. The first column gives the diameters of the grooved sheave-wheels, in which the rope runs, commencing with four feet. Then, knowing the number of revolutions which your shaft makes, the last column gives the horse-power corresponding to a certain-sized wheel. Where there is a choice between a small wheel and fast speed, or a larger wheel with slower speed, it is recommended to take the larger wheel. The horse-powers given are minimum, and can be relied upon under all circumstances.

Distance of Transmission.—"The foregoing table is intended for distances from 80 up to 350 or 400 feet in one stretch. For a single stretch extended to say 450 feet, where no opportunity is presented for putting in an intermediate station, we must use a rope one size heavier; and in a case where there is not sufficient head-room to allow the rope its proper sag, and it has to be stretched tighter in consequence, we must also take a rope one size heavier. Whenever the distance is less than 80 feet, the rope has to be stretched *very tight*, and we no longer depend upon the sag to give it the requisite amount of tension. Here we must take a rope two sizes heavier than is given in the table, and run at the maximum speed indicated: it is also preferable to substitute in place of the rope of 49 wires a fine rope of 133 wires, of the same diameter, which possesses double the flexibility, runs smoother, and lasts longer. In fact, the substitution of a fine rope for a coarse one can be done with advantage in every case in the table where the size admits of it. Both kinds of rope are spliced with equal facility. The

TABLE OF TRANSMISSION OF POWER BY STEAM.

Diameter of Wheel in Feet.	No. of Revolutions.	Trade No. of Rope.	Diameter of Rope.	Horse-Power.	Diameter of Wheel in Feet.	No. of Revolutions.	Trade No. of Rope.	Diameter of Rope.	Horse-Power.
4	80	23	3/8	3.3	10	80	19 18	5/8 11/16	55. 58.4
4	100	23	3/8	4.1	10	100	19 18	5/8 11/16	68.7 73.
4	120	23	3/8	5.	10	120	19 18	5/8 11/16	82.5 87.6
4	140	23	3/8	5.8	10	140	19 18	5/8 11/16	96.2 102.2
5	80	22	7/16	6.9	11	80	19 18	5/8 11/16	64.9 75.5
5	100	22	7/16	8.6	11	100	19 18	5/8 11/16	81.1 94.4
5	120	22	7/16	10.3	11	120	19 18	5/8 11/16	97.3 113.3
5	140	22	7/16	12.1	11	140	19 18	5/8 11/16	113.6 132.1
6	80	21	1/2	10.7	12	80	18 17	11/16 3/4	93.4 99.3
6	100	21	1/2	13.4	12	100	18 17	11/16 3/4	116.7 124.1
6	120	21	1/2	16.1	12	120	18 17	11/16 3/4	140.1 148.9
6	140	21	1/2	18.7	12	140	18 17	11/16 3/4	163.5 173.7
7	80	20	9/16	16.9	13	80	18 17	11/16 3/4	112. 122.6
7	100	20	9/16	21.1	13	100	18 17	11/16 3/4	140. 153.2
7	120	20	9/16	25.3	13	120	18 17	11/16 3/4	168. 183.9
7	140	20	9/16	29.6	14	80	17 16	3/4 7/8	148. 141.
8	80	19	5/8	22.	14	100	17 16	3/4 7/8	185. 176.
8	100	19	5/8	27 5	14	120	17 16	3/4 7/8	222. 211.
8	120	19	5/8	33.	15	80	17 16	3/4 7/8	217. 217.
8	140	19	5/8	38.5	15	100	17 16	3/4 7/8	259. 259.
9	80	20 19	9/16 5/8	40. 41.5	15	120	17 16	3/4 7/8	300. 300.
9	100	20 19	9/16 5/8	50. 51.9					
9	120	20 19	9/16 5/8	60. 62.2					
9	140	20 19	9/16 5/8	70. 72.6					

splices are all of the kind known as the long splice; the rope is not weakened thereby, neither is its size increased any, and only a well-practised eye can detect the locality of one.

It is not necessary that the two wheels should be at the same level, one may be higher or lower than the other without detriment; and unless this change of level is carried to excess, there need be no change in the size of wheel or speed of rope; the rope may have to be strained a little tighter. As the inclination from one wheel to another approaches an angle of 45°, a different arrangement must be made."

Driving Ropes.—"The range in the size of wire ropes is small, varying only from $\frac{3}{8}$ inch to $\frac{3}{4}$ inch diameter in a range of 3 to 250 horse-power. The ropes are always kept on hand, and can be spliced endless at the factory; or else a man is sent to splice them whenever an endless belt cannot be put on direct. Where a rope-transmission has to be constantly at work, it is good

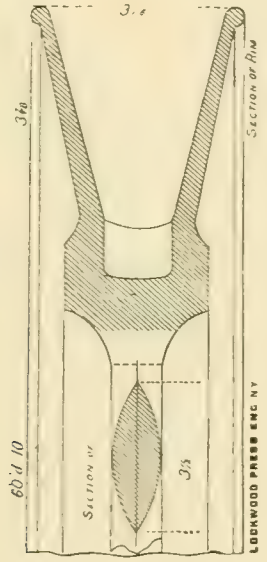


FIG. 135.—GENERAL IDEA OF SHEAVE FOR WIRE ROPE.

policy to keep a spare rope on hand ready spliced, so as to avoid delay. Their duration is from two and a half to five years according to the speed. For the smaller powers it is advisable to take a size larger, for the sake of getting wear out of the rope, although it must be borne in mind that a larger rope is always stiffer than a small one, and therefore additional power is lost in bending it round the sheave. An illustration of that is seen in the case of the 14-foot wheel in the table, where a $\frac{7}{8}$ rope gives less power than a $\frac{3}{4}$ rope, simply because it is so much stiffer. Ropes for this purpose are always made with a hemp core, to increase their pliability." Fig. 135 shows the proper form of sheave and groove.

Sheaves for Wire Rope.—It is necessary that the rims and grooves should be turned truly, and the wheels very carefully balanced, and not only the groove must be filled with some kind of packing to increase the grip and lessen the wear of the rope, but the sides of the flanges must be protected by

leather fastened by rivets. In Fig. 136, B shows this lining, which extends between the packing and the flanges.

Deflection of Ropes.—"When the upper rope is the driving rope, it will become more or less tense on starting the power, thus causing the lower rope to sag from a direct line between the wheels about one half more than when the rope is still. This is of importance, as it should be known beforehand whether the lower rope is going to scrape on the ground or touch other obstructions. Whenever the direction of the motion of the driving wheel is not fixed by other circumstances, it is often advisable to make the lower rope the driving or pulling rope, and the upper rope the follower. In this way

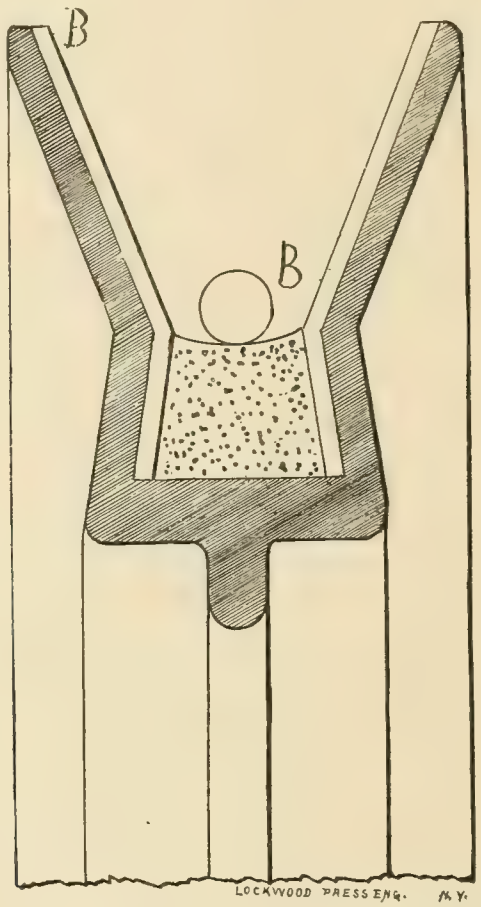


FIG. 136.—LINING WIRE ROPE SHEAVES.

obstructions can be avoided which by the other plan would have to be removed. In Fig. 137 the upper rope is the driver, and the lower one, having little or no tension, sags very far out of the horizontal. When the ropes are not driven, both sides take the position shown by the curved dotted lines. To find out how low the under rope will come when the top one drives, hang up a wire and let it come down about one-thirty-fifth the distance between the wheel-centres. The lower rope will hang about one-half more below the horizontal line than when at rest. The upper one, when driven, will hang about one-forty-fifth or one-fiftieth instead of one-thirty-fifth the

distance between wheel-centres, below the horizontal line. In Fig. 138 the lower rope is the driver and the upper one the loose rope. It will be seen that in this case the sag is very different from what it was in the former. When a rope is very long it is advisable to take up the stretch at the end of two or three months, as a slack rope does not run so steadily as a tight one. The rope while running requires no protection. If it has to stand still much, pour some hot coal-tar from a can on the rope in the groove of the wheel while running. Whenever there is no room for the sag of the rope, and it is inconvenient to raise the wheels higher, or a ditch cannot be dug, it may be supported by a roller in the middle. This supporting-roller must be in the middle of the span, and must be at least half the size of the larger wheels."

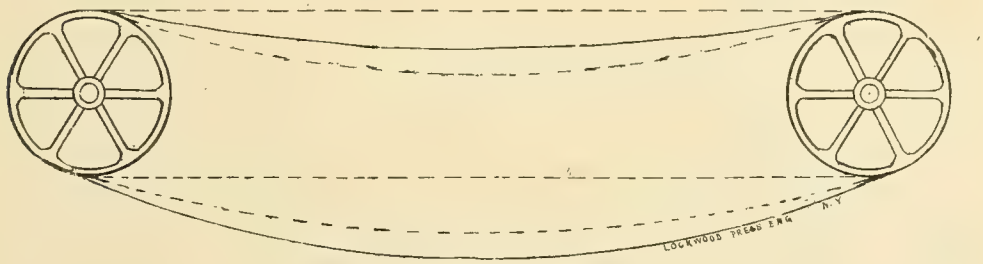


FIG. 137.—UPPER ROPE DRIVER.

Long Transmissions.—"When the distance materially exceeds 350 to 400 feet, a rope-transmission should be divided into two or more equal parts, by means of one or more intermediate stations. At each station there is a wheel mounted on a pedestal or other support, and provided with a double groove in the rim; so that in place of one long continuous rope, we have two or more shorter endless ropes, extending from station to station. This is far preferable to supporting-rollers in the middle, especially when the demand on the power is intermittent and jerks would thereby be caused in the rope. With the two-grooved wheel that cannot take place: moreover, the wear of the rope on a supporting-pulley is greater. The whole system

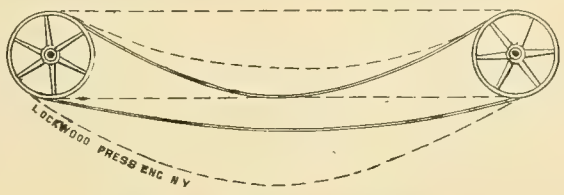


FIG. 138.—LOWER ROPE DRIVER.

should be in a straight line from end to end. The number of stations can be extended indefinitely. Transmissions are in operation a mile in length. The loss of power from friction, etc., or bending of rope, does not amount to 10 per cent. per mile, and need not be taken into account at all for only one station. No slipping of the rope in the groove ever occurs with a proper fillign. The pedestals for the two-grooved wheels may be built of stone, iron or wood. It is usually cheaper to make a wooden frame butted to a

masonry foundation extending below reach of frost. The frame should be braced from each side so as to maintain the wheel in a vertical plane; end bracing is not required."

Rope Connecting Rods.—The cuts, Fig. 139, show in plan and elevation, a system of rope connecting rods, giving a positive drive through long distances. As will be seen, there are upon each shaft three cranks, 120° apart,

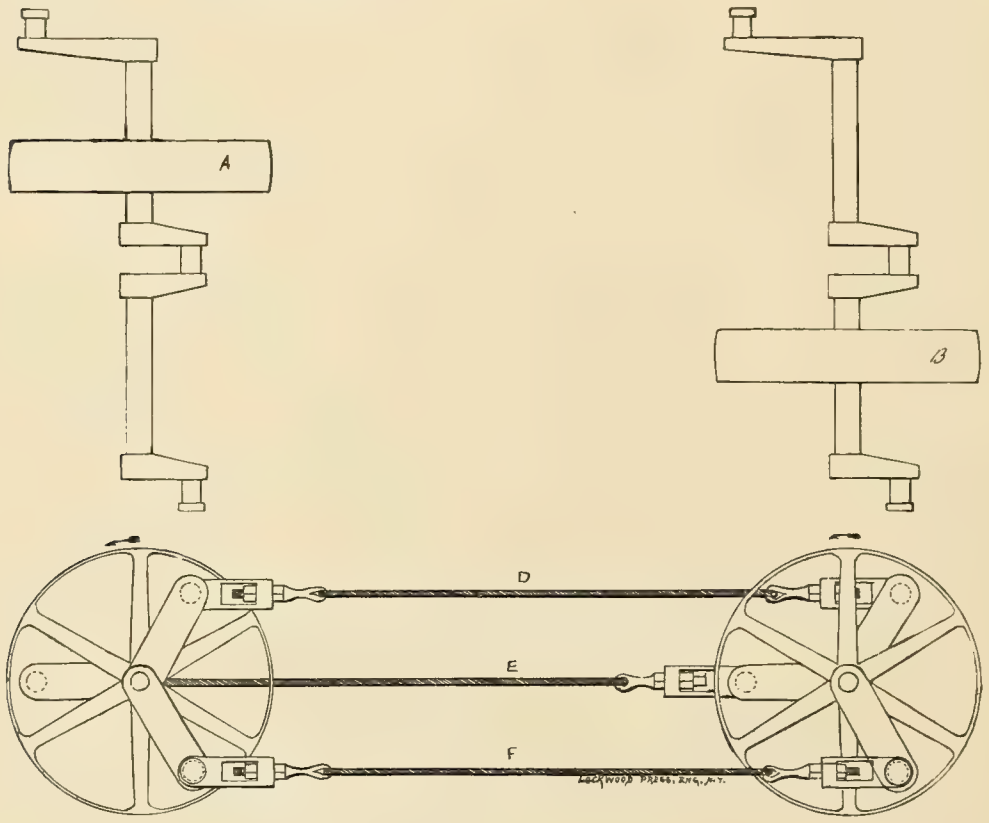


FIG. 139.—WIRE ROPE CONNECTING ROD.

and each having a stub end. Each pair of stub ends is connected by tightly strained wire, of course, of equal length. When the axles revolve in the direction shown by the arrows, and when they are in the position shown in the cuts, the rope D will be in tension, E will be neither slack nor taut, and F will be slack. This arrangement may be driven at slow or fast speed, thus giving an advantage over the wire rope in its ability to be run slow; while its motion is as positive as that with rigid connecting rods.

CHAPTER XVII.

FRICTION AND LUBRICATION.

Friction — Function of Lubricant — Hot Bearings — Lubricants — Compounded Oils — Evaporation — Spontaneous Combustion — Purity — Action of Oils on Metals — Bearing Metals — Proportions of Bearings.

Friction.—Friction among solids is of two kinds, rolling and sliding, governed by different laws. The laws of the friction of journals (which includes both solid and fluid friction), are quite different from the laws of friction of solids, as given in text-books. Fluid friction varies with the square of the velocity, is proportionate to the area of the rubbing surfaces, and probably independent of the pressure. A fluid lubricant forms a fluid cushion, separating the surfaces more or less perfectly according to its viscosity. The same surface lubricated with a given material may, under light pressures, seem to be governed by the laws of fluid friction, while under heavy pressures, the lubricant being squeezed out from between the solid surfaces, the laws of friction of solids come into play. The ratio of frictional resistance to total pressure from sliding friction varies directly as the pressure. It is independent of the speed and area of the rubbing surfaces. The laws of solid friction differ with the character of the rubbing surfaces. The friction of fibrous materials is increased by increased extent of surface and time of contact, and is diminished by pressure and speed. With wood, metal and stone (within the limit of abrasion), it varies only with the pressure, being independent of the extent of surface, contact and velocity. This limit of abrasion is determined by the hardness of the softer of the two materials. Friction is greatest with soft materials, and least with hard ones. The friction of lubricated surfaces is determined by the lubricant rather than by the solids.

With rotating journals, friction is greater when the journals or bearings are not round, than when they are truly cylindrical; greater when they are short than when long; greater when there is much wear than when there is little; greater when the surfaces are not finely finished than when they are of perfect surface; greater when improperly lubricated than when duly supplied with a fit lubricant; greater at high speed and pressure than at slow.

Bearing surface must be given by length rather than by diameter. It is the weight per square inch of *longitudinal section* that determines the heating and friction. Bearings cannot run cool unless the minute high places on them are either removed or reduced, and the low places are filled up with some sort of unguent. If the caps of journal boxes are left too loose, the

journal will wabble, and if screwed down too tight, the lubricant will burn out and the bearing become ruined.

Function of Lubricant.—The function of a lubricant is to provide rollers by which the movements of one surface upon another are rendered easier, besides which it distributes the pressure, making the journal press upon the bearings upon nearly all points of the semi-circumference, if its axis is horizontal, instead of upon a few points only. Of course, the diameter of a journal is slightly less than that of the box it runs in. The shaft being smaller than the box would touch at only one point, if it was not for the lubricant which fills the annulus between the two surfaces and distributes the pressure. The proper time to oil a box is a long while before it gets hot. Every time that you heat a box you are wasting power and destroying your bearing surfaces.

The amount of tension on the belts very seriously affects the quantity of power required to drive a machine. In spinning threads, it has been found that if the amount of tension on the bands is increased from two pounds to four, the power would be increased 31 per cent., six pounds, 59 per cent.; eight pounds increased 97 per cent. Some people seem to think that oil is simply to stop squeaking and to make things run easier; and because oil is necessary that it shows that machines are imperfectly made. Consequently the oil bill seems to be paid less cheerfully than any other about the establishment. Many a manufacturer in endeavoring to save a few gallons of oil loses several tons of coal. The axial pressure is stated by Radinger to be three times as great with pulleys as with gears.

Hot Bearings.—It has long been known that sulphur cools a hot bearing, but the reason why is doubtful. Von Heeren states that the fine metal dust formed when a journal runs hot, and which strongly acts upon both journal and bearing, forms a sulphide with the sulphur. This compound, which grows soft and greasy, does not cause any appreciable amount of friction. Sulphur and grease, in combination, are in regular use on board the steamers of the North German Lloyds. Oil should not be poured on heated journals. This is wasteful, and water is a better cooler. Graphite in oil is of use to prevent as well as to cool hot journals. Heating of the bearings may be from want of truth in the bearings themselves, or from their running dry. To see whether a shaft is true, hold a point steadily against it.

Lubricants.—The value of a lubricant simply as a lubricant is independent of its cost. The heat of friction has several ill effects; it reduces the viscosity of the lubricants, making them squeeze out at high pressure; it cracks, breaks and destroys the surface of contact; may ignite the lubricant, thus softening and weakening the abrading metals and causing liability to combustion, and it may weld the journals in their bearings. Lubrication is intended to reduce friction and prevent the development of heat. An efficient lubricator should have enough "body" to keep it from being squeezed out, but as far as is consistent with the former the sum of the two frictions, solid and fluid frictions, should be small. It should have high capacity for receiving, transmitting and storing heat, and for carrying it away. It should neither decompose nor change in composition, either in exposure to the air

or in use. It should be free from acid or from any liability to injure materials with which it may come in contact. It should evaporate or decompose at a very high temperature and solidify at a low one. It should be especially adapted to the speed or pressure at which it is used, and be free from grit and all foreign matter. The character of lubricants used should vary with the surfaces rubbing together, with the speed they run, with the pressure. Sperm oil is one of the very best known lubricants, but high in price. Lard oil is more used; it is cheaper and not so good. Some oils reduce friction well, but do not wear well, or cannot be kept on the journals. Linseed oils and the drying oils gum. Tallow is apt to contain acids or to form them. Some lubricants congeal at low temperatures; others cannot be used in steam cylinders because they decompose or evaporate.

One of the best lubricants is graphite, also called plumbago and blacklead. When of proper fineness and purity, it packs itself between the projections, filling them up level. Being a solid, it is especially adapted to those places where there is great pressure, which would likely squeeze out any liquid lubricant; and being unalterable by heat, it is less likely to be affected than oils, which are unstable in their compositions. Being unaffected by cold, it never gives any trouble by gumming or thickening. But it must be perfectly pure, tough, free from grit, and of the proper sized particles. The best of which the writer has any knowledge is made by the Dixon Crucible Company, Jersey City, N. J. It is put up in several shapes and in several grades. For millstone spindles, the grade called "perfect lubricator" should be used. For vertical smutters, separators, and brush machines, the same grade of graphite should be used as for heavy machinery, except that it should be prepared in oil and not in grease, and so prepared as to remain in suspension in the oil. Thus prepared, the makers claim that it will feed freely through an ordinary oil-can. For engine slides, there is difficulty in feeding anything but the very finest oils, and graphite as yet has not been successfully used for them. For wooden bearings graphite is especially to be recommended.

At low temperature the viscosity of kerosene is equal to that of lubricating oils at the average temperature of bearings in general use; hence we find kerosene of use in extremely cold situations, as under great cold its fluidity is enough to cause it to enter the bearings.

A person wrote to the *American Machinist:* "I desire to know the value of castor-oil for machinery. Is there any acid in it? If you have any articles upon castor-oil as a lubricant, please send me the same, in order that I may obtain some light." The reply was as follows: "Castor-oil has an exceedingly heavy body, and at a temperature of 59° Fahrenheit has a specific gravity of .9667, while the best bleached winter sperm has a specific gravity of .8813, and lard winter a specific gravity of .9175. Castor-oil is an exceedingly durable lubricator. During some tests which were made on a testing machine belonging to the Lake Shore and Michigan Southern Railway, fifty drops of the different oils tested were used at one application, and the machine, which has a journal corresponding to the size of a car journal and subjected to an equivalent pressure, was driven at a speed representing thirty-five miles per hour, until the temperature shown by the thermometer rose

from 60° to 200° Fahrenheit. The following is a summary of the test which shows the endurance of the oils tested:

Castor, . . .	12,946 rev.	West Va., . .	7,915 rev.
Paraffine, . .	11,685 "	Sperm, . . .	7,912 "
Mecca (black), .	9,982 "	Tallow, . . .	7,794 "
Neatsfoot, . .	8,277 "	Lard, ...	7,377 "

These tests have been criticised, but as the railroad company continued to use the cheaper oils it may be taken as evidence that they are at least approximately correct. There are some objections to the use of castor-oil for general lubrication, the most prominent of which is its cost.

Fully one-half of the oil used in mills for lubrication is wasted. The author knows of a manufacturing establishment where the hangers of their line shafting work perfectly with only thirty-four drops of oil each per week. To determine the viscosity and rate of gumming of oils, place a drop of each sample on the top of an inclined plane, and note the time required to run down. Of the ungumming oils, the least viscous will reach the bottom first. Of the gumming oils, the quickest drying are the slowest to reach the bottom. The smaller the mill, the greater the advantage in using good lubricants. In large mills the cost of a horse-power averages only $50 per year, but for small powers it runs to four times that; hence a lubricant saving 5 per cent. would save $500 per year where 100 horse-powers are used. The amount of oil used would run only from 40 to 100 gallons. It would be cheaper for the consumer to pay $5 or even $10 per gallon for a good article than to accept a poor one as a gift.

There is one thing that is not generally taken into consideration, and that is, that different sizes of bearings require different lubricants, and that different pressures also require different means of lubrication. Some oils are penetrating, some are viscous; some readily enter between the bearing surfaces, some do not; some are easily forced out from between the surfaces by excess of pressure, some are not. Some oils are good for high speeds, some for slow. Those that are good for high speeds are not good for the same bearings at slow speeds. I might say in reply to a special query: "for steel surfaces lubricated with the best sperm oil, and moving slowly, 1,200 pounds per square inch of bearing surfaces permissible;" but if the conditions were different, the reply would be different to correspond. If the surfaces were rougher and softer, if the oil was of a poorer quality, or if the speed was higher, the pressure admissible would have to be reduced, and if the pressure was unchangeable and the bearings were less perfect, the speed would have to be reduced to prevent heating. If the gross pressure, and the material of the bearing, or the speed could not be changed, then the bearing would have to be lengthened, so as to make the pressure per square inch much less.

So eminent an authority as Professor Sweet says in reference to the question of economy by reduction of friction, that of two systems—one offering a saving of 10 per cent. by reduction of friction and the other of 20 per cent. in the use of steam, he would take that which led to a saving in friction, which of necessity implies saving in maintenance, attendance, repairs, delays, etc. This loss by attendance, repairs and delays is greater in small engines

than in large. To get economy in friction there should be generous wearing surfaces, well fitted and properly lubricated, and the engine should be in absolute alignment, We often find shafts which are set in perfect line and remain so when at rest, but which are deflected by the strains put upon them while at work.

Owing to the smaller cost of the lighter volatile oils, they have been extensively used in mills for lubricating, instead of the better but higher priced oils; but the fact that the heavier and more expensive oils are really the cheapest lubricants is now more generally recognized by mill owners. The discovery of this fact, based on statistical tables of the relative quantities of cloth made and the amount of lubricant used during its manufacture was brought about in a very curious way, through the instrumentality of the Boston Manufacturers' Mutual Insurance Company. The attention of the insurance company was drawn to the greater liability of light oils to take fire through spontaneous combustion and friction, or producing highly inflammable vapors, the ignition of which cause dangerous fires, resulting in loss of life and property. Edward Atkinson, president of the company, in August, 1878, collected data from mill owners showing the relative amount of lubricants used to cloth produced. The average amount for 56 mills was from 1.03 to 2.88 gallons of oil for every 1,000 pounds of cloth from 33 yarn. In 1880 similar data were collected from mills insured by the company and using heavier and safer oils; and there was found to be 33 per cent. saving in favor of the safer and better lubricants, representing $180,000 gain by the seemingly more expensive lubricants. Now, if from this we take 40 per cent. for the reduction in price in oils between the years 1878 and 1880, we have $100,000 absolute profit from the use of the better oils. These figures are not hypothetical, but are the results of carefully collected data from mills representing over 4,000,000 spindles. This principle of economy is available for all classes of mills.

Compounded Oils.—A very objectionable class of oils consists of mixtures of light and heavy oils, residues from still bottoms, having light oils added to them to give a consistency and deceiving gravity, but under the heat of steady work the light oils are volatilized and the lubricating power of the oil lessened, while the fire risk is increased.

The flashing point of lubricants is important to know, because the danger of fire from the use of any oil is not determined from the point at which the oil itself ignites, but by the lower temperature at which the vapor that rises from the oil bursts into flames. Thus, a smutter employing an oil which gives off a vapor igniting at a temperature of 140° F., would be in danger, because the temperature of 140° would be likely to be reached if the oil supply ran at all low, or the tension of the bands were increased by overlacing, and the vapor which extends as far as the fine dust, given off the machine would be liable to inflame and set fire to the dust, which would in turn communicate the flames to the whole mill. Outside of the question of fire risk, if the lubricant gives off at the running temperature, a volatile vapor, and yet does not permit it to inflame, there is a certain amount of oil that has been paid for, which does no work in lubrication.

Evaporation.—Mineral oils by evaporation lose at 140° from one to thirty per cent. Animal oils gain slightly in weight at that time owing to oxidation.

Spontaneous Cumbustion.—To estimate the tendency to spontaneous combustion, take a given weight of cotton wool, saturate it wholly or slightly with the oil in question, put it in a confined place and note the rising temperature in twenty-four hours.

Purity.—To know the freedom of a lubricant from acid, observe its effect upon a cleaned copper plate.

Action of Oils on Metals.—At a meeting of the British Association, Prof. William Henry Watson read a paper upon the action of certain oils on metals, which is a valuable contribution to the literature relating to lubricants. At the Plymouth meeting of this association he brought forward the results of some experiments, showing the action of various oils on copper, and the conclusions arrived at were briefly these: 1. That of the whole of the oils used, viz., linseed, olive, colza, almond, seal, sperm, castor, neatsfoot, sesame and paraffine, the samples of paraffine and castor-oils had the least action, and that sperm and seal oils were next in order of inaction. 2. That the appearance of the paraffine and the copper were not changed after seventy-seven days' exposure. 3. That different oils produce compounds with copper varying in color, or in depth of color, and, consequently, rendering comparative determinations of their action on that metal, from mere observations of their appearances, impossible. He was disposed to conclude that these experiments would indicate the relative action of the oils on other metals, simply expecting that the extent of action would vary throughout, but that the variations would be proportionate between the oils. Since the publication of these results, however, an interesting paper appeared in the *Pharmaceutical Journal*, "On the Action of Paraffine Oils on Metals," by Dr. S. Macadam. He comes to the same conclusion as Professor Watson with regard to their action on copper, but, referring to iron, "it is slightly affected by paraffine oil, and on ten days' contact the oil becomes deeper in color and throws down a fine ferruginous sediment." Owing to this, Professor Watson lately made experiments on the action of the same oils as those previously used on copper and on iron, and the results, which are the subject of this communication, are interesting, as showing that there is no relation between the action of an oil on copper and the action of that oil on iron; that, in fact, in several instances, those oils which act largely on iron, act slightly on copper, while those which act largely on copper act little on iron. Of course, the actual extent of action of the same oil (with the exception of paraffine) is greater on copper than on iron. In addition to the oils used in his experiments on copper, he also used a sample of lard oil, and a special lubricating oil. The following observations were made after twenty-four days' exposure: 1. Neatsfoot.—Considerable brown irregular deposit on metal. The oil slightly more brown than when first exposed. 2. Colza.—A slight brown substance suspended in the oil, which is now of a reddish-brown color. A few irregular markings on the metal. 3. Sperm.—A slight brown deposit, with irregular markings on the metal. Oil of a dark brown color. 4. Lard.—

Reddish brown, with slight brown deposit on metal. 5. Olive.—Clear and bleached by exposure to the light and air. The appearance of metal same as when first immersed. 6. Seal.—A few irregular markings on metal. The oil free from deposit, but of a bright red, clear color. 7. Linseed.—Bright deep yellow. Oil bleached and free from deposit. 8. Almond.—Metal bright. Oil bleached and free from deposit. 9. Castor.—Oil considerably more colored (brown) than when first exposed. Metal bright. 10. Paraffine.—Oil bright yellow and contains a little brown deposit. The upper surface of the metal, on being removed, is found to have a resinous deposit on it. 11. Special Lubricating.—Metal bright. Appearance of oil not perceptibly changed. The samples were then chemically examined, and the amounts of iron found in them were as follows :

Oils.	Grains.	Oils.	Grains.
Neatsfoot (English)	0.0875	Seal	0.0050
Colza	0.0800	Castor	0.0048
Sperm	0.0460	Paraffine	0.0045
Lard	0.0250	Almond	0.0040
Olive	0.0062	Special lubricating	0.0018
Linseed	0.0050		

For comparison, the following are the results obtained of the action of these oils on copper, as previously communicated, after exposure of ten days :

Oils.	Grains.	Oils.	Grains.
Neatsfoot	0.1100	Linseed	0.3000
Colza	0.0170	Seal	0.0486
Sperm	0.0030	Paraffine	0.0015
Olive	0.2200	Almond	0.1030

Owing to the length of exposure being different in the two series, we cannot fix on the actual differences in the rate of action of any of the oils on the two metals. However, it is shown that almond oil, which acted largely on copper, acts very lightly on iron ; in fact, with the exception of the paraffine and special lubricating oil (a mineral preparation), it acted less than any of the other oils on iron. The same is shown, as already mentioned, as to the action of various other oils ; thus, while sperm oil acts slightly on copper, it acts considerably, compared with the others, on iron. Linseed, seal, castor, almond and paraffine, may be bracketed as having about the same and very little action on iron, while linseed, olive, neatsfoot, almond and seal have the greatest action on copper.

Bearing Metals.—All persons are not of the opinion that phosphor bronze is the best. A large rolling-mill owner says that he prefers first-class copper and tin for his work. He has large experience, and is a close observer, and says that the heat of the rolls acts badly on the phosphor bronze, besides, he suggests that copper and tin bearing is cheaper. Even *real* babbitt-metal is not always found to be of such great value, as it gets particles of grit imbedded into it, and thus "laps" a place in the shaft and reduces the diameter. There are numbers of instances of that, and in such a case the place where the bearing is cannot be changed. Some claim that it takes more power to run it than cast iron. Brass or babbitt-metal has this advantage over iron for bearings of wrought-iron journals; outside of its lesser

coefficient of friction, it conducts the heat away from the journal more rapidly than cast iron does. Wherever the pressure exceeds 125 pounds per square inch, projected area, brass or soft metal bearings should be used. Each class of work should have a bearing material to suit it. In choosing, be governed by the experience of others under exactly similar circumstances; and by records of tests made to show just what qualities each material has.

Proportions of Bearings.—Bearings should in most cases be long, to distribute the pressure and wear; and the journals should be of as small diameter as stiffness will allow, to lessen the leverage of the resistance.

CHAPTER XVIII.

BACKLASH AND SIDE PULL.

Backlash—Coil Spring—Side Pull.

Backlash.—Backlash is largely caused by the fact that the crank acts with greatest force when at right angles to the piston rod, and with least when on the dead centres. Thus there are two points in each rotation when the crank leads the burrs, and two when it is led by them. Making the fly-wheel very large and heavy remedies the defect, to a certain degree, because a body resists change of speed in the direction of its motion just as much as in the opposite direction. Having fly-wheels of great diameter should drive from its rim, for the purpose of giving the machinery leverage over the engine has no such result; besides which, the cost of the motor is increased.

One cause of backlash is the elasticity of the belts. A pair of wheels not properly mated at their pitch lines, and not pitched and trimmed properly, will always backlash. Backlash is often caused by wheels being bored out of centre. It is said by some that one way of stopping backlash is to make the rim of the fly-wheel lead the skirt of the stone by $\frac{1}{3}$; thus, if the skirt travels 2,400 feet per minute, the rim of the fly-wheel should travel 3,200. This is entirely wrong. The motion indicator will show at any time whether the burrs are running too fast or not, and whether there is backlash enough to interfere with their proper running.

Coil Spring.—The evil of backlash is successfully combated by the Eureka Coil Spring. This is made of three plates of cast spring steel, riveted together at the inner or hook end. The lengths of the springs are so proportioned that the strain on the outside, which is the thickest plate, is tensile, while that on the inner plates is prehensile. Its length is seven and a half feet. Fig. 140 shows the spring in its casing, applied below the pinion, which is loose on the spindle, and rests on the centre hub of the spring, which is keyed fast to the spindle. The two opposite arms of the pinion fit into the corresponding edges of the casing, which is fitted to play easily and freely on the head, to which the inner end of the spring is fastened, as is shown at A, Fig. 141. Its outer end is fastened to the casing by a bolt, as shown at W, Fig. 140. Thus the connection between the spindle and the pinion is elastic. When the gearing is spur and there is not enough space on the spindle below the pinion, it is advisable to raise the crown wheel and pinions enough to let the spring go underneath. The pinion can thus be raised out of gear in a few moments, while the spring remains keyed fast to the

spindle. The automatic stop prevents the spring from being injured by backing the engine.

There is an oil cup which is filled with wick and placed on the spindle above the pinion when the spring is applied below, so as to lubricate the pinion, spindle and spring. The hub, or sleeve, ought to be faced off flush with the arms of the pinion ; but if it extends beyond on the side where the spring is to be applied, the casing must be made accordingly. The key that is between the spindle and sleeve must be taken out in every case, for the vibration must be between the spindle and sleeve, and not between the sleeve and pinion (except when especially designed, and the sleeve is provided with a flange for the pinion to rest on). Where pinions have no sleeve, as shown in Fig. 140, the millwright must be governed accordingly. Square spindles require special treatment.

Fig. 142 shows the spring applied above the pinion. This is generally done when there is not enough space on the spindle below the pinion, or when the lower side of a bevel pinion is too small, so that the casing of the spring, which is sixteen inches diameter, would come in the way of the driv-

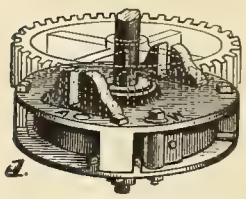


Fig. 140.

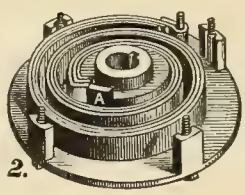


Fig. 141.

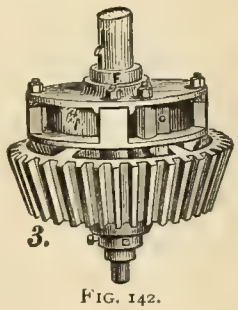


Fig. 142.

ing wheel. It is best to have a key with a large head, which can be lifted loose with a light bar (a feather can only be used when the pinion has a sleeve), and thus raise the spring with the pinion. It requires a wrought-iron collar to go below the pinion when the spring is applied above, but no extra oil cup, as the hub of the spring has a recess for oil. Springs ought to be applied on the spindles of each pair of burrs ; thus, each burr works independently, and is not affected by the others, nor is it subject to any irregularity of the cogs ; and when the machinery is driven both by steam and water, a large spring should also be applied at the connection, so that each motor (engine and water-wheel) applies its power independently, and neither affects or is affected by the constant irregularities of the two forces. When applying this spring, be careful not to drive the key too hard so as to wedge the hub against the casing and lock it. Be sure that the casing plays freely on the hub, and the pinion free on the spindle. Chip the driving side of the jaws of the casing so they have equal bearing and hold paper on both arms ; mark the arms and jaws so that they go together the same way every time. The arms of the pinion must not rest on the bottom of the gap between the driving jaws. The device can be applied in one or two hours.

Side Pull.—Two objections which have been made to the use of belts in driving millstones are the side pull on spindles and variable tension. The

equilibrium driving pulley, made by John A. Hafner, Pittsburg, Pa., has been devised to overcome these objections. In Fig. 143 is shown the improved form of this pulley, of which the following is a description:

A A, is the hub of the driving pulley, the arms being curved from the top of the hub to the centre of the rim in order to bring the centre of the rim on a line with the centre of the hub, so that the pull of the belt will be squarely on the bearing. B B are bushings set in the bridge-tree to form a bearing for the hub. C is the mill spindle resting on the step G. The bore of the hub A is larger than the spindle, the latter having no connection with the pulley except through the equalizing driver E and Hafner's Eureka Coil Spring D. Oil is fed in through an ordinary oil cup and pipe J, the pulley hub resting on the collar F, and the oil being prevented from leaking out by

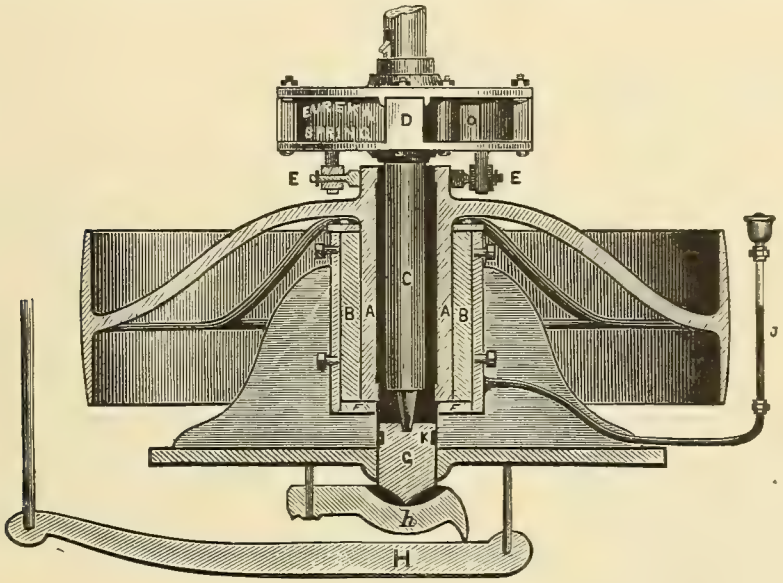


Fig. 143.—Hafner's Equilibrium Driving Pulley.

the packing K, in the groove in step G. The spindle is raised and lowered by an ordinary lighter screw acting through the compound levers H *h*, by which all tendency to throw the step sideways or out of tram is avoided. The quantity of oil in the bearing is indicated by the glass tube J. Thus the side pull on the spindle is prevented by the hub of the pulley A revolving in the bearing B, and receiving the strain of the belt instead of the spindle C. Variable tension of the belt is also counteracted by the elasticity of the coil spring D. The spindle, therefore, free from all outside influences, simply rotates on its pivot, and a perfect motion is secured. To tram the pulley with the spindle, tighten the belt the same as when driving the stone; fasten a tram-staff on the spindle above the spring. The staff is curved down so as to reach the rim of the pulley, which is adjusted by set-screws on followers.

CHAPTER XIX.

GRAIN CLEANING.

Cleaning—Ending—Screens—Grading and Separation—Hungarian System of Cleaning—Cockle—Cockle Separation—Oat Separation—Grader and Dustless Separator—Smutter and Separator—Wheat Brush.

Cleaning.—The object of cleaning is fourfold: First, to extract from the wheat as thoroughly as possible all dust, dirt, clay, stones, and foreign substances which would tend to impair the quality of the flour, together with the beard and crease dirt in the berry itself; second, to extract any light, shriveled, or soft berries that are among the sound ones; third, to remove any grass, cockle, oats, and other seeds, clean or otherwise, that it may contain; fourth, to insure that it is perfectly dry.

Cleaning ordinary grain may be divided into the operations of wind separation, scouring, magnet separation, and brushing. In some mills grading and ending are employed; and where the grain is musty or damp it requires drying and sweetening before any other operation. Musty grain may be made sweet and sound by immersing in boiling water. All the decayed grains swim on the surface. The good heavy grain should then be dried. Heated wheats may have their musty or "ship" smell removed by the use of sulphur and sal-ammoniac on a clear fire, allowing the fumes to pass through the grain.

The wheat-cleaning machines should be placed so that they can be easily reached and carefully looked after by the miller without extra trouble or going up to the top of the mill or the farthest corner of the basement. Cleaning machinery is often stuck in some dark corner, simply because it makes a dust. Where the machines are in the way elsewhere, cleaning and grading can be done in an outside building or in a good light basement, thus giving more room for the bolting and purifying operations. Some seasons' wheat is very dirty; some localities furnish dirtier wheat than others; and some kinds of wheat are easier cleaned than others. Wheat will be more than ordinarily foul to have more than one pound of dirt per bushel of sixty pounds (by dirt meaning foul stuff of all kinds). Good wheat should not have half a pound of dirt per bushel. In California and Oregon small stones in the wheat are troublesome.

Since the advent of the wire-binder, attention has been called to the presence in wheat of pieces of wire, etc., and the *et cetera* is found to be small nails, tacks, bits of sheet iron, pieces of elevator cups, rivets, pieces of the threshing machine cylinder or teeth, pins, needles, and in some localities "black gravel," which is iron ore—altogether quite a miniature junk-shop. A

thousand bushels of wheat were run through the spout in the celebrated Washburn B Mill, Minneapolis, and the magnets took out seventy-three pieces of wire and seventy-one pieces of other metallic substances, consisting of three tacks, two ends of cut nails, one end of horseshoe nail, and sixty-five small bits of wrought iron and sheet iron, varying in size from one-eighth to a quarter inch, in irregular shapes, many of them appearing to be scales or fragments broken from badly worn machinery. Discriminations against wire-bound wheat are hardly practicable, and yet if they do not strike fire the tiny bits of wire are flattened out by the burrs and become tiny saws. The wire-binder is responsible for two-thirds of the iron found in the wheat. It is a mistake to suppose that magnets can take out other than iron or steel particles. The magnets should follow the wind separation, as there is then less liability of clogging in the spouts. Magnets are best put in spouts where currents of air work in the wheat. Fig. 144 shows the magnets arranged in parallel rows, and Fig. 145 arranged in a better manner, obliquely in the spout.

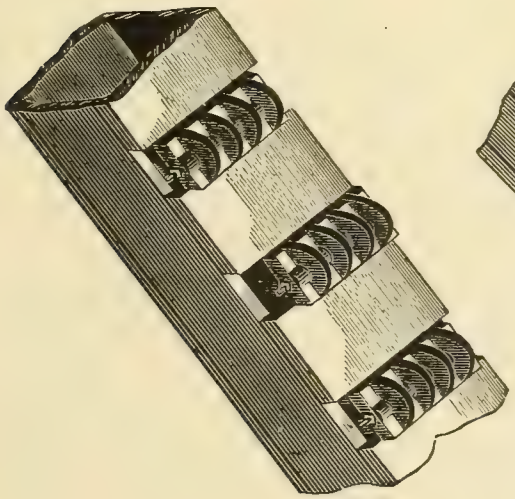


FIG. 144.

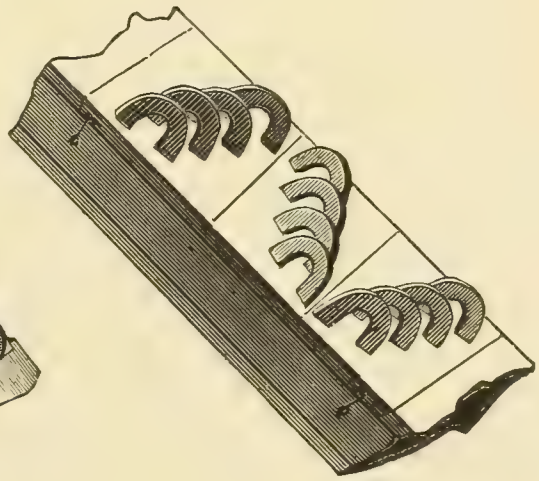


FIG. 145.

MILL MAGNETS.

As magnet makers we can recommend the Harris Safe Works (S. H. Harris, proprietor), Chicago, Ill.

There are three principal modes of separating light grains and wheat from heavy and foreign seeds and other impurities. These are the sieve, blower, and rubbing. Sieving or screening takes advantage of the different shapes and sizes of the bodies to be separated. Light grain, dust and chaff are taken out by suction or blast fans. The oat grain is got out by taking advantage of its elongated form. The light or blasted kernels and the straws or chaff are removed by an aspirator. Friction should remove the hairy fibres or fuzz from the end of the berry and all dirt adhering to the grain. It should leave the grain smooth and polished, without breaking the bran. Any cleaner that breaks wheat causes a waste. There is no use in saying that wheat cannot be cleaned so that there shall be no fuzz on the end of the grain, because this not only can be done, but is done every day in many

mills. The fact that it is not done in nine mills out of ten only shows that there is room for improvement there.

Where winter wheat alone is to be cleaned fewer sieves can be used in separation, and there being no oats to take out, a larger hole can be used in the sieve, thus giving greater capacity. Placing the separator on the grinding floor (especially for spring wheat) has the advantage that it is under the eye of the miller, who can give it the necessary attention without running up and down stairs. Wheat cleaned before shipping not only transports and keeps better, but brings a higher price than that which has not been cleaned. Separation before storage prevents choking when feeding to the cleaning machine. Wheat sieves will clean rye also. While oats can be cleaned on corn sieves, this plan is not recommended, being too slow to suit shippers. Oats are very difficult to remove from spring wheat, requiring small holes in the sieves and an extra number of sieves. Adding a set of sieves with holes especially adapted to remove oats from wheat will, while taking out all the oats, reduce the capacity of the machine fully one-half. The capacity of a separating machine is about one-fourth to one-third less for corn or barley than for wheat. The scouring machine is not intended to remove straw, chaff, stones or nails. It should break all the smut balls and not break the wheat. A screen 18 feet long, 30 inches in diameter, and making 30 revolutions per minute, with a fall of 9 inches, ought to clean 40 bushels per hour. To take out cheat, long narrow meshes are requisite; for cockle, small square meshes will answer. It is, however, much better to buy one of the excellent special scouring and brushing machines than to make one.

It is surprising how much more attention is paid to the subject of cleaning than formerly. Millers are commencing to realize that the earlier they take out the dirt, and the more dirt they take out, and the more careful they take it out, the better chance there will be for white flour, other things being equal. In one way the cleaning may be improved, in large mills at any rate. The Simpson & Gault Mfg. Co. states that when several machines are worked together (as a separator, smutter and brush), the dirt taken out will weigh from 3,000 to 5,000 pounds per 1,000 bushels, depending upon the quality of the wheat, the amount of cleaning it gets in threshing, etc. This seems excessive. "Little and often" is a good motto for cleaning; that is, if there is a certain amount of work to be done, that it should be done by constant rather than by sudden action.

A custom mill should be so constructed that the grain can be cleaned before it is weighed. The miller knows what he is getting. Clean every grist, then weigh it, and book it. Grists range from one to ten pounds of dirt to the bushel. One authority states that he has cleaned as many as fifteen pounds out of a few grists. Such grists are made up largely of screenings, and are "made to sell."

Millers should try to impress upon farmers that it pays them to deliver clean wheat, and they can emphasize what they say in this connection by showing them the result of carelessness upon the wheat trade of our Pacific coast. In some districts there is trouble with what is called the Texas pea, about one-third larger than the ordinary cockle, and almost impossible to separate.

One of the greatest nuisances in Pennsylvania is the presence of *garlic*, which gums or clogs up the burrs, requiring them to be frequently scrubbed or to have a special dress. Sometimes the nuisance is lessened by the rolling cockle screen with cup-shaped indentations; but in any case, the presence of garlic in any great quantities is the cause of annoyance and loss in burr mills. Strange to say, in some sections, as the interior of Pennsylvania, the garlicky wheat that the millers are troubled with comes from farmers who are wealthy and never sell until midsummer. Some kinds of wheat, as Michigan, are best treated without scouring, the brush taking care of it well enough. A great many mills have no room nor power to run both a smutter and a brush machine. For this class the combined smut and brush machine is recommended.

There are some machines employed in the cleaning of grain that ought to be entered as *disintegrators*, such and so damaging is their action upon the grain. The smut machine that breaks all the smut balls and does not break the wheat is the one the miller should buy.

Cockle is most plentiful in Wisconsin, Minnesota, Dakota, Northern Iowa and Nebraska. The offal in cleaning is about two pounds per bushel of cockle and similarly-shaped seeds. Where there is not a special cockle-extracting machine, cockle is more readily separated after being reduced in size by the smutter.

Ending.—It is especially claimed for ending stones that they break no wheat and take little power. Before ending, the wheat should be graded in three different lengths by sieves or screens with a gentle end motion. For ending, a good quality of sandstone is used. The stones should be put up for work like ordinary burrs, the upper one running. The dress of the runner should be such as to draw the grain in rather than to throw it out. A rigid runner should be used, and the faces kept apart at such a distance that the grain is not touched unless revolving on end. They should be taken up and dressed every three days. The bed-stone should have no furrows, but a good deal of bosom, say 30 inches in a 5-foot stone. After the ending stone the wheat is sent to an ending reel. The refuse (points and a little flour and bran) goes to another reel. The flour is dark and the bran very poor. The points are ground with the bran into very low grade flour.

Screens.—A screen 18 feet long, 30 inches in diameter, and making 30 revolutions per minute, should clean 40 bushels of wheat per hour. The form of the meshes should be chosen with reference to the nature of the offal to be taken out. Cockle needs small square meshes and cheat long narrow meshes. A shaking screen is more liable to clog up than a rolling one. Whatever be the material employed it should be evenly punched without burr or bulge. It is by far the best to buy these screens ready punched, but in places where this cannot be done in time the metal can be punched with a steel punch upon a large cake of lead, or upon the end of a large block of hard wood, this last needing to be cut off from time to time, as it gets too much indented, and the lead needing to be hammered smooth. If it is possible to have two rolling screens they will work better than one, because the second screen may have smaller meshes than the first, and the small plump

grains of wheat which may have passed the meshes of the first will be stopped by the second.

There are two principal types of screens, those woven of wire and those

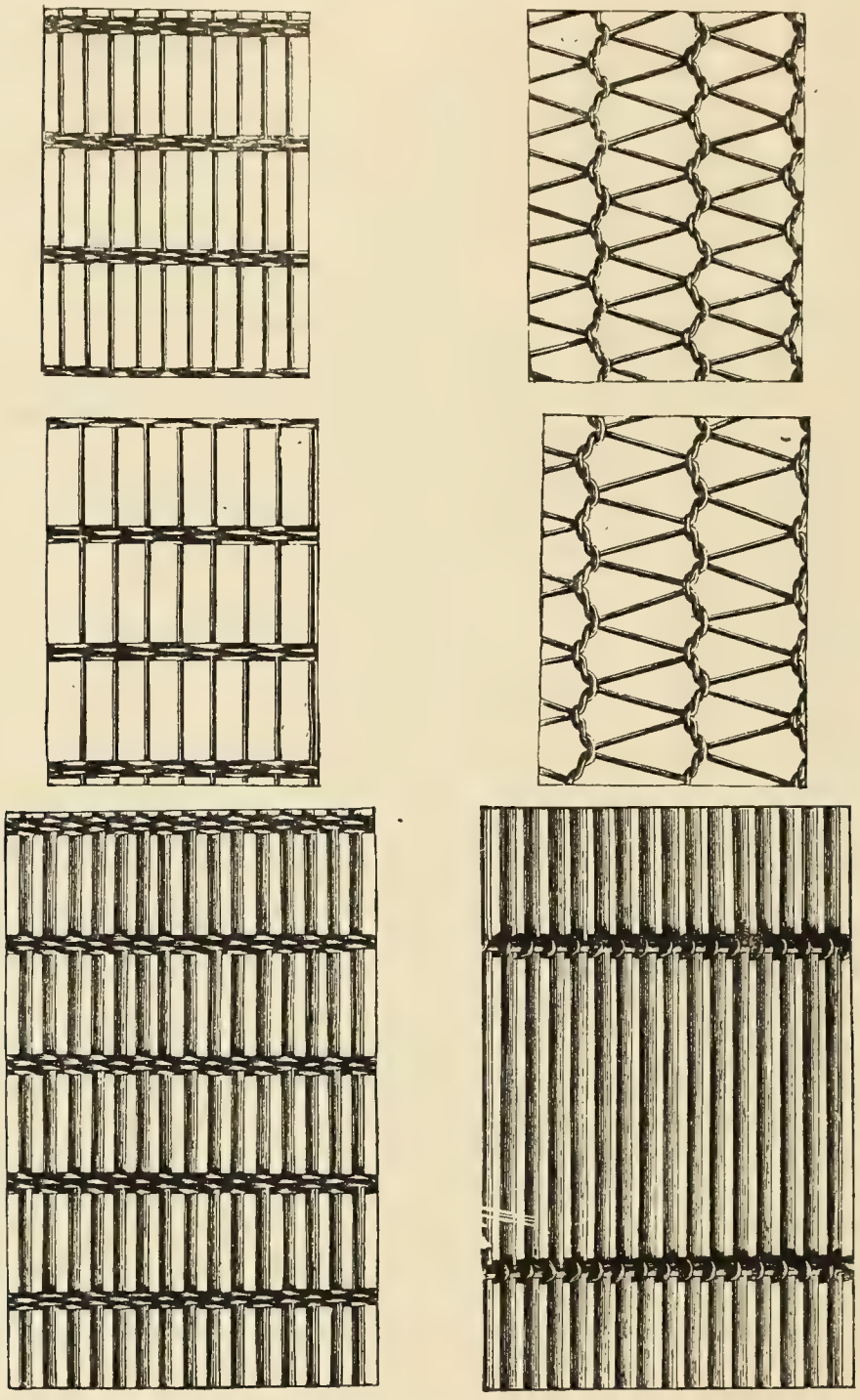


Fig. 146.

made of perforated plates. The first have naturally greater screening capacity (as far as mere separation according to size is concerned) than the second class; but in the second class there is a greater adaptability to sep-

aration, according to shape ; and this, added to their superior durability and their cheapness, makes them the most common and popular in this country.

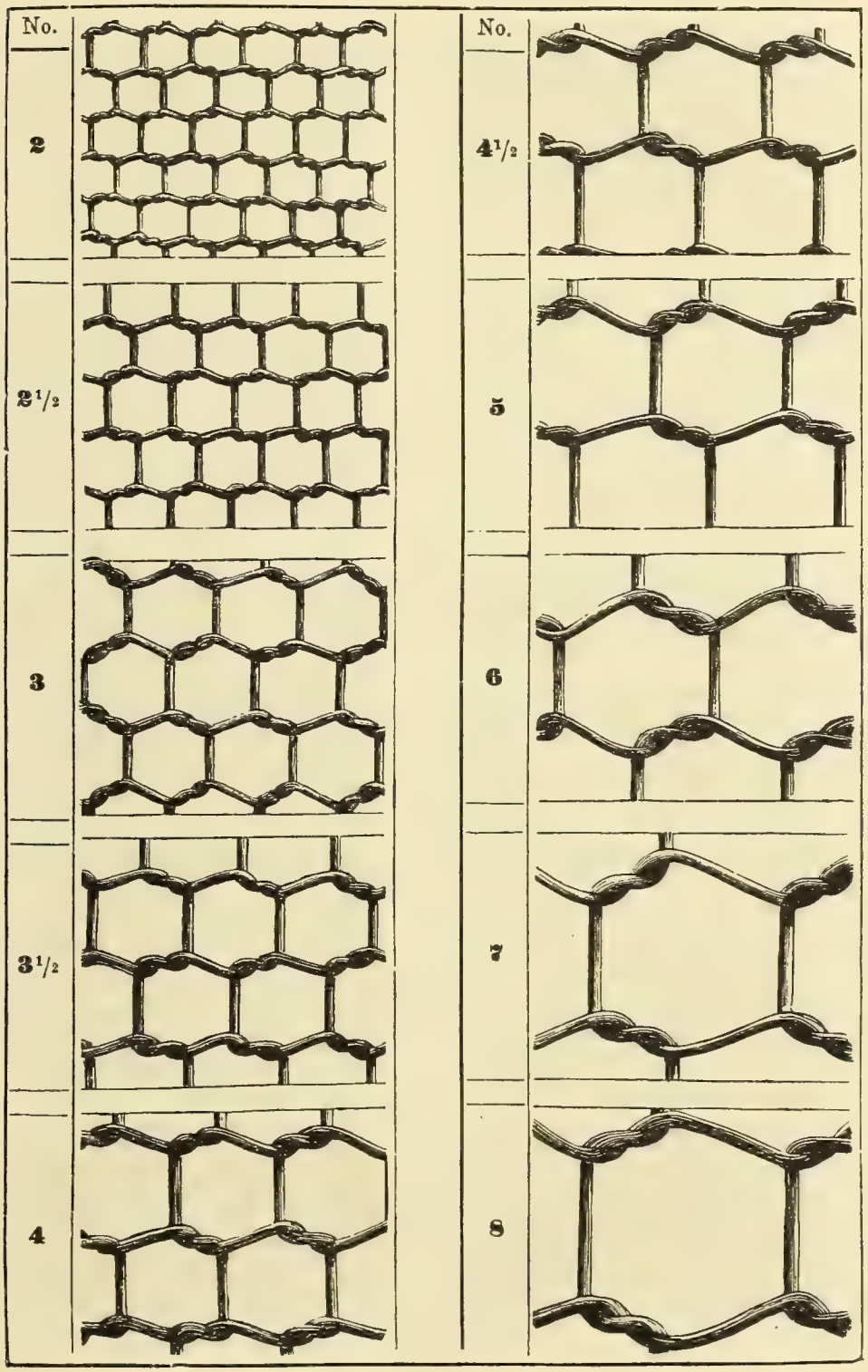


Fig. 147.

The cut shows a number of styles of screens, in their natural sizes. It will be noticed that there is one style which is made of rods or bars running

lengthwise and wattled together by wires, so as to leave very long unobstructed spaces. Fig. 146 and part of Fig. 147 show a style of machine very

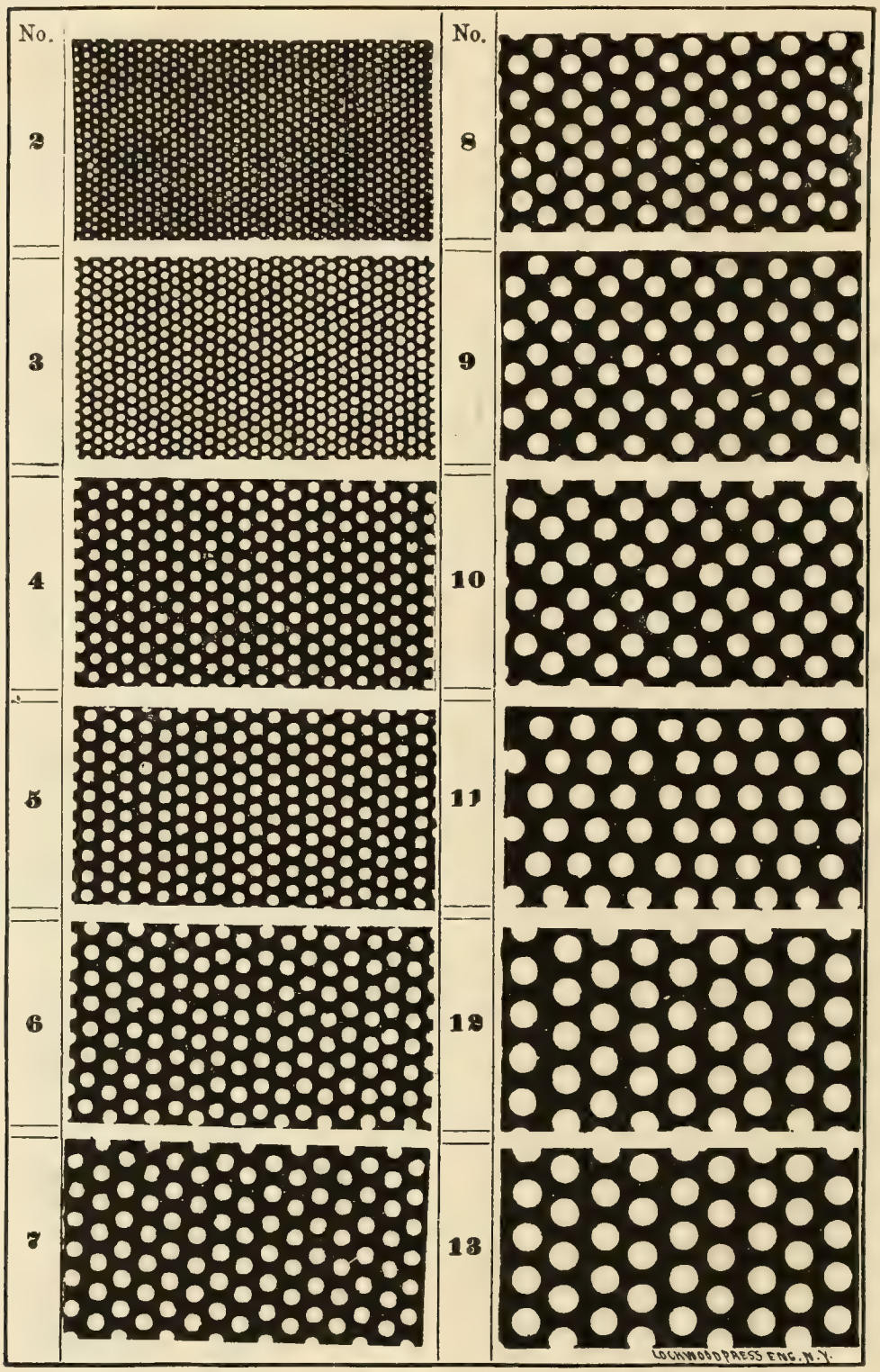


FIG. 148.

common abroad, especially with Swiss houses. It has the merit of having openings more nearly approximating to round holes than the ordinary square

mesh made in this country. The figures attached give the foreign numbers. Perforated screens, which are the rule in this country for mere grading to

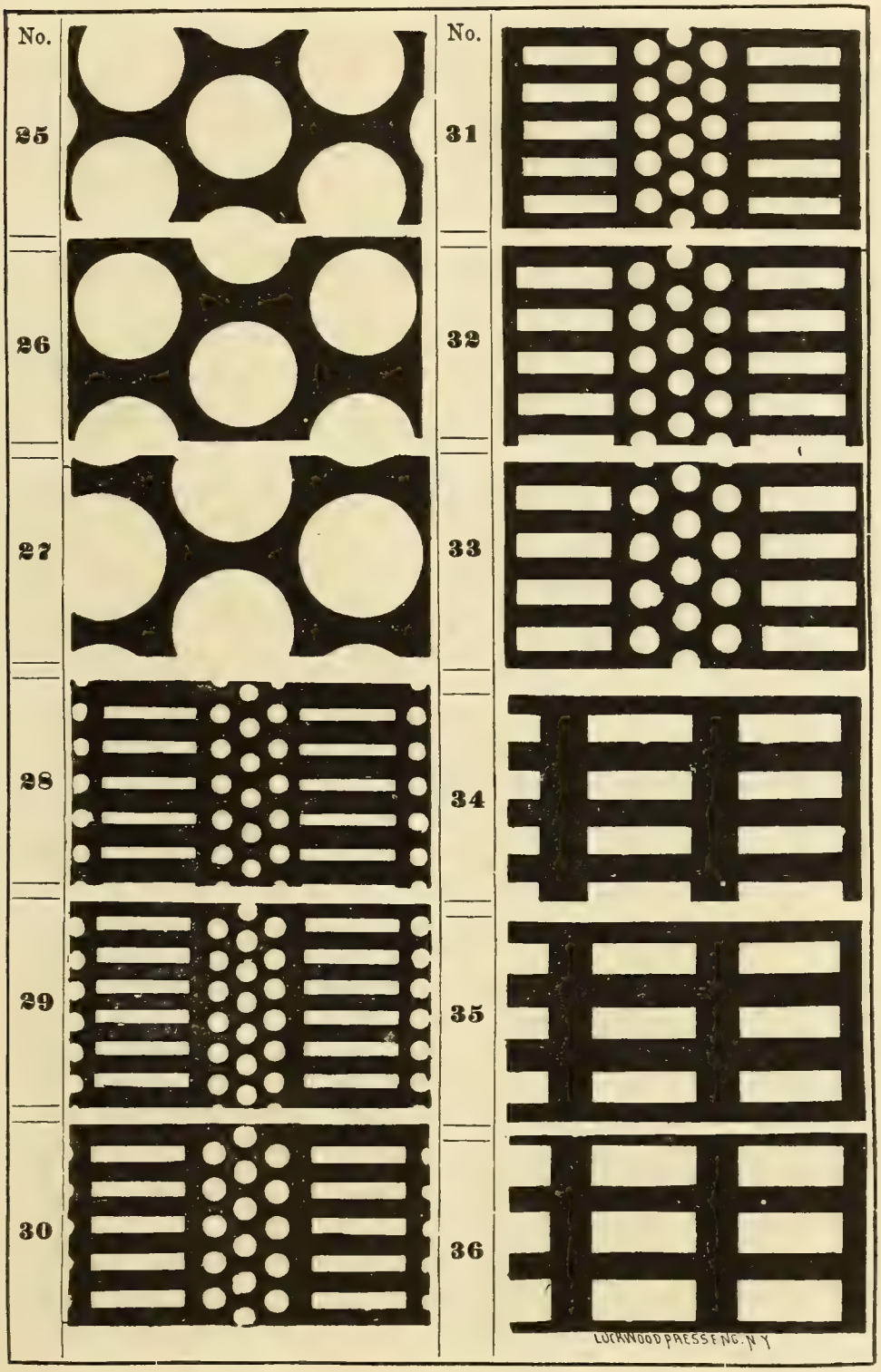


FIG. 149.

size, have three principal shapes of holes—round, oblong and triangular—these varying in size, spacing and arrangement. Round and triangular holes

are generally arranged "staggering"—that is, the holes in one row alternate with those in another. Oblong perforations are generally arranged in paral-

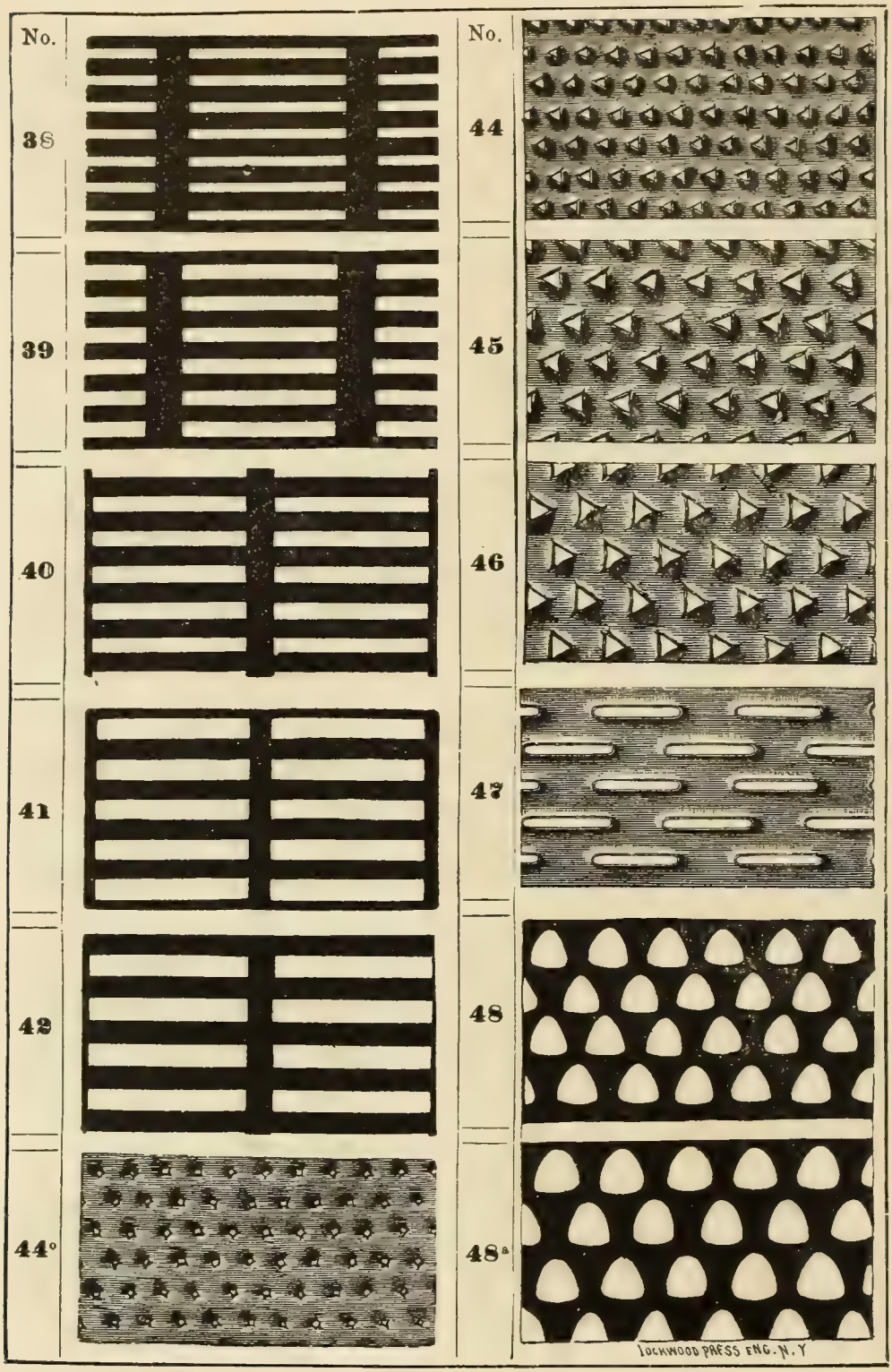


FIG. 150.

lel rows. Referring to Fig. 148, Nos. 2 to 5 are employed for sieving and screening, grading middlings, bolting corn meal, etc., up to $\frac{3}{64}$ of an inch

in diameter. No. 6 ($\frac{1}{16}$-inch perforation), No. 7 (of $\frac{1}{14}$-inch hole), and No. 8 ($\frac{1}{12}$-inch), take out flax and all small seed. No. 9 ($\frac{3}{32}$ of an inch),

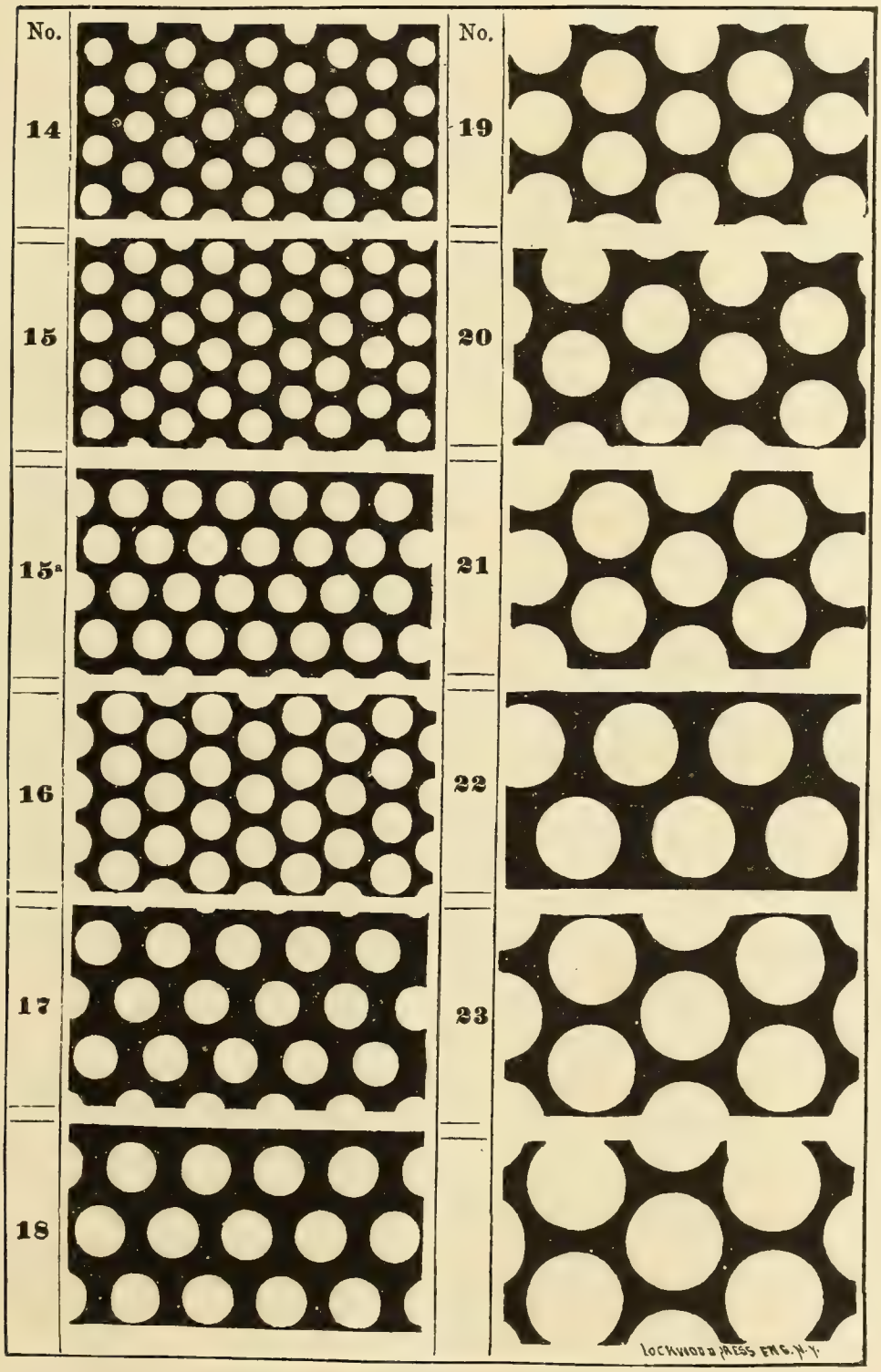


FIG. 151.

10, 11 ($\frac{7}{64}$ inch), 12 and 13 ($\frac{1}{8}$ inch), are for cockle and flax seed. Of the perforations shown in Fig. 149, Nos. 25 ($\frac{1}{12}$ inch), 26 ($\frac{9}{16}$ inch), and 27

($\frac{5}{8}$ inch), are for oats and corn. Nos. 28 to 36 are little used in this country. In Fig. 150, Nos. 38 to 42 are for generally screening purposes; No. 44 is for scouring grain. Nos. 44 to 46 are used in scourers, pearl barley machines, hominy mills, etc. Nos. 47 and 48 are not now much used in America, although demanded abroad. For timothy, there is demanded $\frac{1}{16}$-inch hole; smutters take long slots, $\frac{1}{16} \times 1\frac{3}{4}$ inch; flax, $\frac{5}{32} \times \frac{5}{8}$ inch, with round ends; oats, $\frac{1}{4} \times 1\frac{1}{4}$ inch, with round ends. Kiln floors for drying oats, etc., may have holes either round or $\frac{1}{16} \times \frac{1}{4}$ inch, oblong, but should be of No. 16 iron at least. Round holes, $\frac{1}{2}$ inch in diameter, answer for oats and corn. Elliptical perforations, $\frac{1}{2} \times \frac{3}{4}$, answer for corn. For barley and flax, $\frac{3}{16} \times \frac{3}{4}$ inch oblong holes, with round ends, are used. Wheat takes $\frac{3}{16}$, $\frac{1}{4}$ and $\frac{7}{32}$ inch round holes. $\frac{5}{8}$ inch and $\frac{3}{4}$ inch round will answer for corn; and the same shape, $\frac{1}{4} \times \frac{5}{8}$ inch, does for oats. Barley takes $\frac{5}{16}$ inch round; $\frac{3}{32}$ inch round answers for cockle, and $\frac{1}{8}$ inch round for cockle and flax. Some smutters take what is called lip style, the perforation being of ∩ shape, and left projecting like a tongue.

In Fig. 151 are shown several other styles. No. 14 ($\frac{5}{32}$ inch round) is for buckwheat and flax; No. 15 ($\frac{11}{64}$ inch), the same; No. 15A ($\frac{3}{16}$ inch), for wheat; No. 16 is the same, but the rows run the other way across the sheet; No. 17 ($\frac{7}{32}$ inch) is for wheat; No. 18 ($\frac{1}{4}$ inch round), for wheat, used in separators, threshing machines, etc.; No. 19 ($\frac{5}{16}$ inch), used for wheat and barley; No. 20 ($\frac{9}{32}$ inch), for barley and rye; No. 21 ($\frac{3}{8}$ inch), for barley alone; Nos. 22 ($\frac{11}{32}$ inch) and 23 ($\frac{7}{16}$ inch), for oats and barley; and the last one of the set ($\frac{15}{32}$ inch round), for oats alone. The materials employed for these screens are plain and galvanized iron and zinc. This work must be done carefully, or the plates will be weakened and the holes rough. Harrington & Oglesby, of Chicago, are reliable people to deal with in this line.

Grading and Separation.—Many riddles simply measure the grain passing through them, and select only the larger grains. Many small plump grains that measure less than the cockle pass through the riddles, while the larger grains of less weight and value pass on with the good wheat. The fanning mill with riddles is apt to run off with the heaviest wheat with the straw and tailings, when the crank is turned too fast, before it can pass through the meshes of the riddle.

Grading is advisable before smutting or brushing. That which passes over the tail of the cockle separator will be best smutted and brushed by itself and reduced by itself if possible. The small berries should be scoured and brushed separately, because if the machine is set to scour or to brush the large grains it will not handle the small ones as perfectly, and if set close enough to work the small ones it will be too harsh for the large ones. If the wheat has tough, thick bran it will be well to give it a good scouring and one or two brushings; but if it is tender the scourer may sometimes be dispensed with.

There is nothing like careful and thorough separation; but it must be remembered that the machine or the method that will clean one kind of grain is not always the best for all other kinds, and indeed sometimes for any other

kind. And in cleaning different sizes and weights of grain the machine should be adjusted to the different kinds of work it has to do. Sometimes we find people complaining that they cannot clean barley or rye to their satisfaction; but it would be a wonder if they could, because their machines or devices are of the crudest kind and kept in very bad order, if there is such a thing as bad order.

Hungarian System of Cleaning.—The wheat is passed through two 15-feet reels, 3 feet diameter, running 28 revolutions. Each reel is covered with four sheets of wire; two sheets of No. 14 at the head, to let the dust and small seeds through, and two of No. 6, to let the wheat and grain of the same size fall to a hopper. Then comes scouring on two reels.

FIG. 152.

For a 24-run mill they are thus clothed:

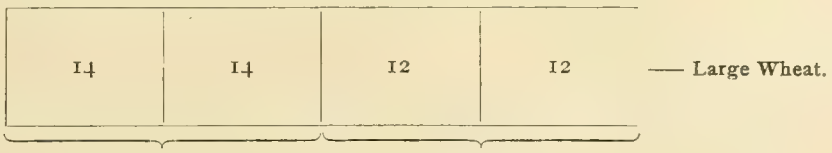


FIG. 153.

The scouring dust is sold for feed, perhaps, and the small wheat for poultry, and then comes separation and grading of wheat, to prevent the light grain making the flour dark. Then comes second grading upon two reels thus arranged:

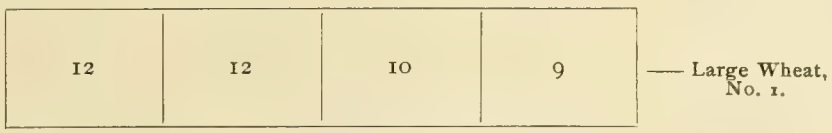


FIG. 154.

The No. 1 large wheat goes to two 4-foot ending stones. Then it goes to two reels clothed with No. 14 wire.

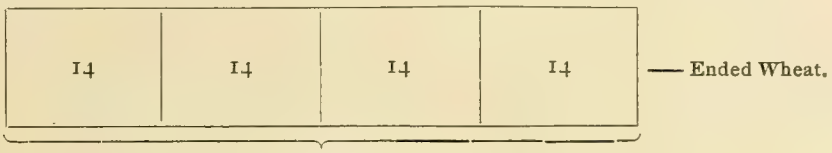


FIG. 155.

Then comes air separation, the last one that is made. While the No. 1 wheat is being ended the other numbers of wheat are being elevated to sepa-

rate hoppers above the ending stone. After No. 1 has been ended the stones are set closer; then, after No. 2 has been ended, they are set still closer for No. 3, and so on.

The roughing of ending stones should be in a semicircular form to assist the delivery of the wheat. The semolina is sent to be sized and cleaned. The mixed flour and middlings go to a reel covered with Nos. 11 and 10 silk.

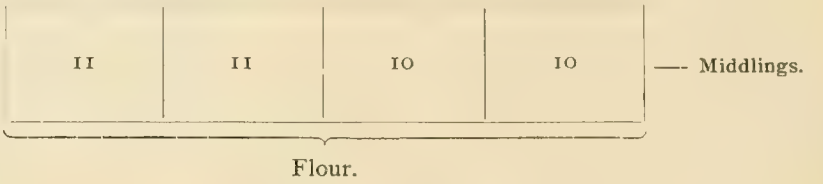


FIG. 156.

The flour is sent to the sacks as first break flour. The middlings are sent to the reel clothed thus:

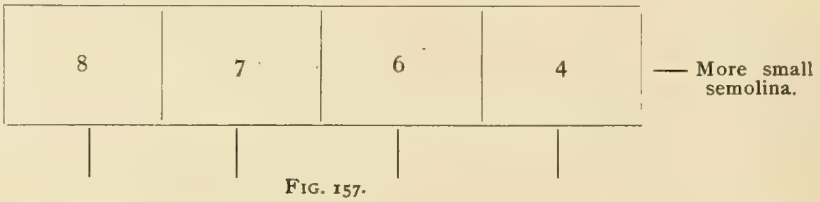


FIG. 157.

The first size, that which tails over, is good, white and free from specks.

Cockle.—In harvesting wheat quite a variety of seeds are gathered with it—seeds which are very good of their kind, but to produce good flour these seeds must be separated from the wheat berry before grinding. Cockle cannot be separated with the "common herd," but requires a special machine adapted to its individual oddities. Cockle is a native of Europe—called *Coquelicot* by the French; and belongs to the order *Caryophillæ*. That variety causing the most trouble is the *Lychnis Githago*. The lobes of the calyx are linear and longer than the corolla, which is of a purplish red. The ovary is solitary, with central placenta. The virtues of cockle are few and slight, and its vices many. It grows even better than wheat on the same soil and is prolific in seed-bearing, "bringing forth plants after its kind" with terrible regularity and profuseness. Cockle when growing is a healthy weed to look at, and is very generous in branching qualities; growing from one to four feet high, varying at the root from almost nothing to one inch, and sometimes even more in thickness. The seeds are borne in pods and are of a very peculiar shape, and it is on this peculiarity that machines are constructed to separate it. The seed is covered with prickly spines and of a black color, and if allowed to get in the flour darken it to a material degree. Fromerly the removal of cockle was attempted by aprons of fuzzy material, such at felt or flannel; the spines catching in the fuzz and being discharged, while the smooth wheat berries were not carried out by the apron. This, however, was found not to give satisfactory results, as the wheat would sometimes be carried over with the cockle. Rolls of hard and of soft rubber felt, corks and flannel rolls were then tried, with the idea of causing the cockle to stick in the fuzz or soft material of which the rolls were made, and

thus be removed. These rolls we remounted at such a distance apart as not to break the wheats, but still close enough to cause the cockle spines to penetrate them. This method was also found ineffectual, as the spines of the cockle would become worn off in the bags by rubbing against the wheat, and, therefore, would not stick in the rolls; and, also, on account of the rolls causing loss of grain by crushing some of the larger wheat berries. The only method of removing cockle by mechanical means seems to have been arrived at by one of our Western firms.* The principle on which these machines depend is the difference in size and shape between the cockle and the wheat. Sheet-zinc cylinders are constructed having indentations on their inner surfaces, which are large enough to accommodate the cockle, but too small to hold the wheat. The whole kernels are first separated from the mixture of broken wheat and foreign seed, and the broken wheat and seeds further separated by the revolving indentated cylinders. The broken wheat is discharged with the whole kernels, while the cockle and other foreign seeds are thrown out by themselves.

Cockle Separator.—Figs. 158 and 159 illustrate the single cylinder cockle machine in plan and section. The illustration Fig. 159, shows the interior of the simple cockle machine without separate attachments, the berries being shown very much too large. The grain falling on the sieve A, the larger grain is tilled over into the spout B, discharging at the large end of the cylinder. The small grain and the cockle pass through the holes in the sieve A, then through the division E, and enter the revolving indented cylinder F. The cockle fits into the indentations, and by the rotation of the cylinder is carried up past the first catch-board and falls into the lower cockle spout. Very small and broken kernels of wheat are carried higher up past the second catch-board, *gg*, and fall into the upper spout, being thus kept free from the bulk of the cockle. As only the ends of the kernels of wheat fit into the indentations, as shown by the small cuts, Figs. 161, 162, 163, 164, they fall out before reaching the lower catch-board; they slide back and gradually work toward the hopper C. Wild buckwheat is similarly taken out. Fig. 160 shows a double machine with parallel cylinders. A double machine is built with two cylinders on the same level, and a quadruple machine, which is a double-deck duplex machine.

Fig. 165 shows Richardson's Dustless Oat Separator combined with the cockle separator. The oat separator removes oats, stones, white-caps, straws chess, dust and dry wild garlic. One section operates on the wheat as it enters the machine and another as it leaves it, this latter being for the purpose of removing any dirt loosened by the scouring action in the cylinder. Each section is independent. The machines have double eccentrics, one to shake the sieve riddle and the other the feed and discharge spouts. The feed hopper has a feed-roll to prevent clogging. The wheat enters the separator through a suction-spout, where it is subjected to a strong upward current of air, regulated by a valve, which removes the screenings, light oats, chaff, etc., the screenings being let through at the drop-spout cleaned, ready for market, while the chaff and dust are drawn into the fan and are blown out of the building;

* Cockle Separator Manufacturing Co., Milwaukee, Wisconsin.

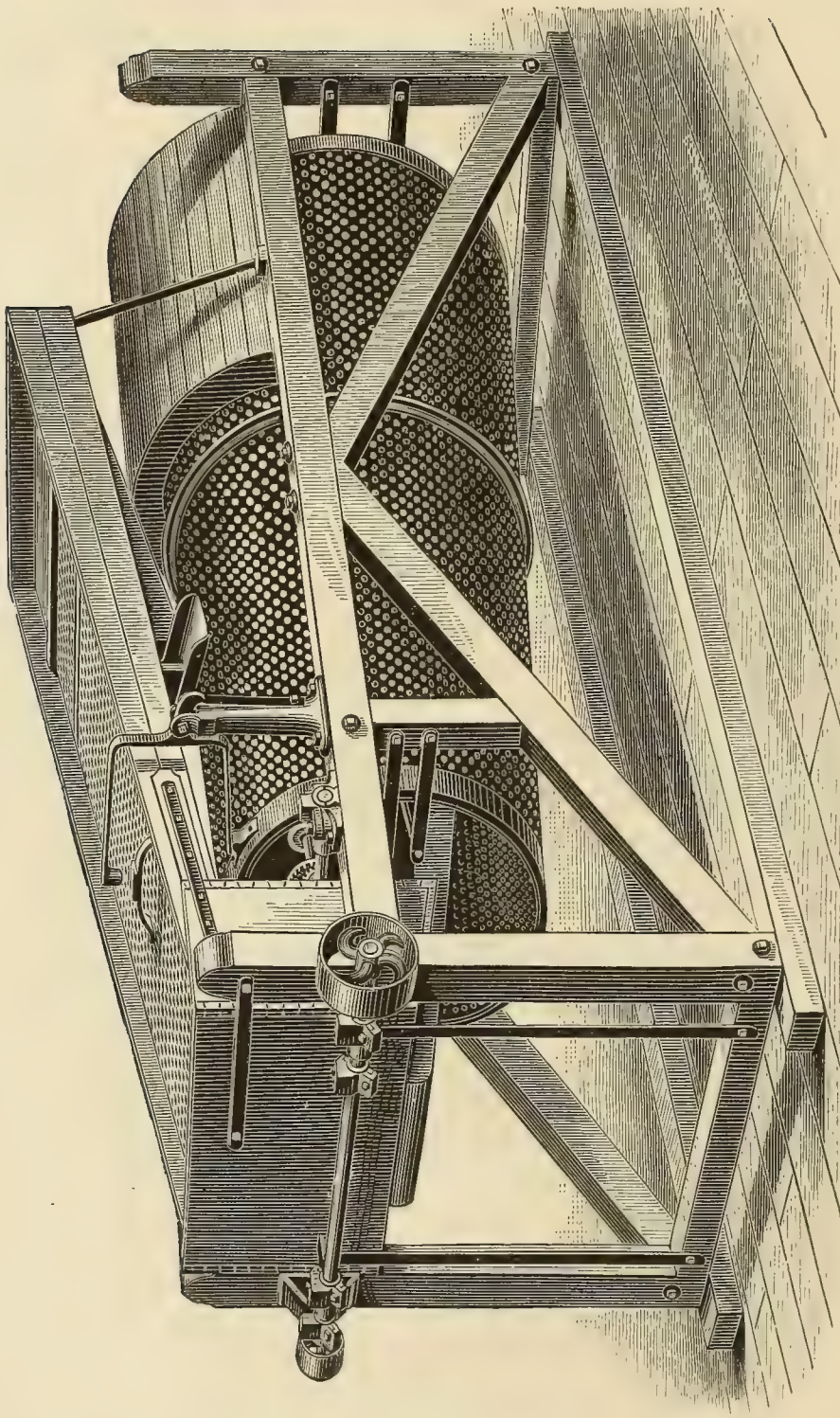


FIG. 158.—SINGLE CYLINDER COCKLE MACHINE. COCKLE SEPARATOR MANUFACTURING CO., MILWAUKEE, WIS.

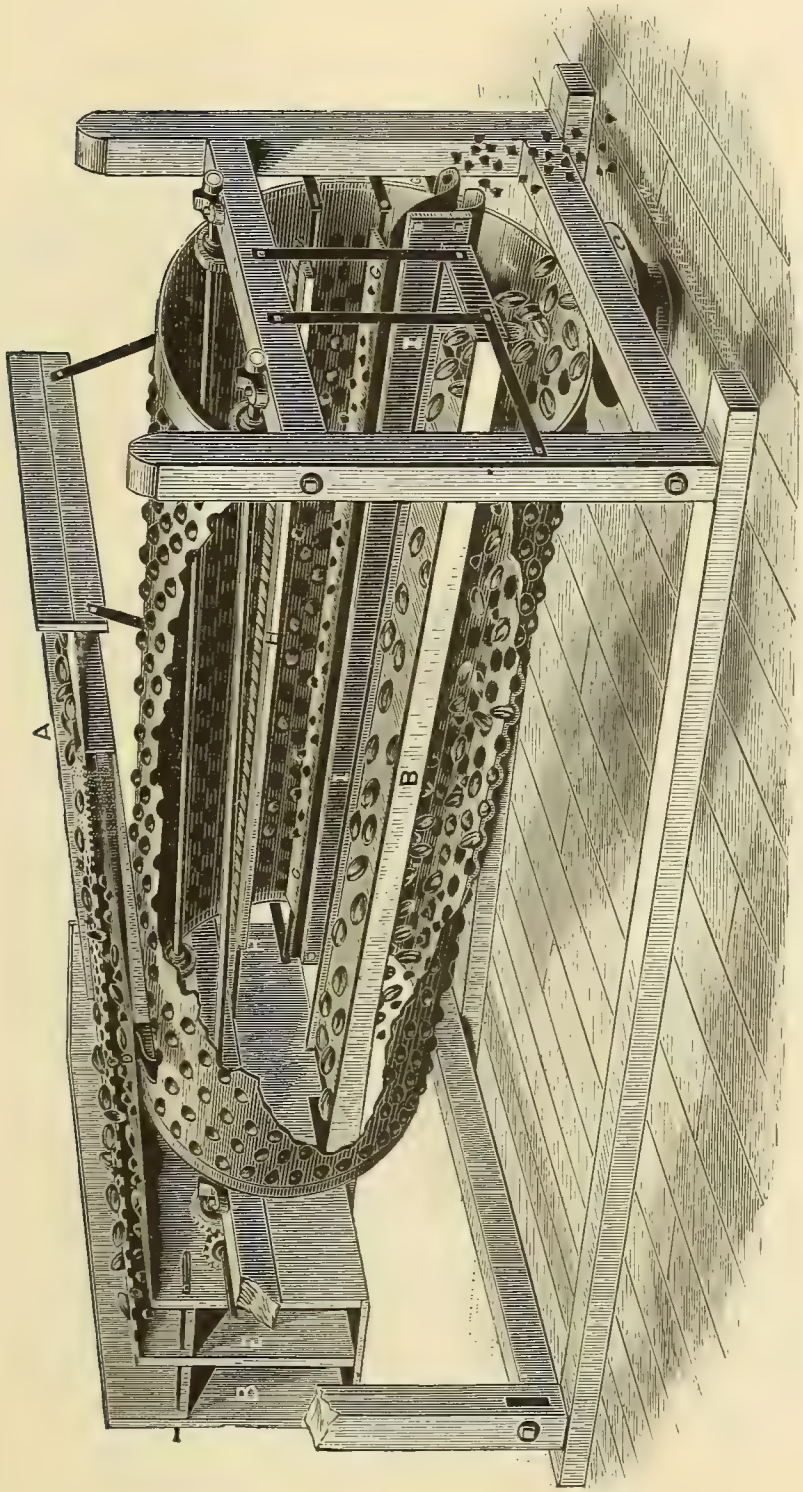


FIG. 159.—SECTION OF COCKLE SEPARATOR. COCKLE SEPARATOR MANUFACTURING CO., MILWAUKEE, WIS.

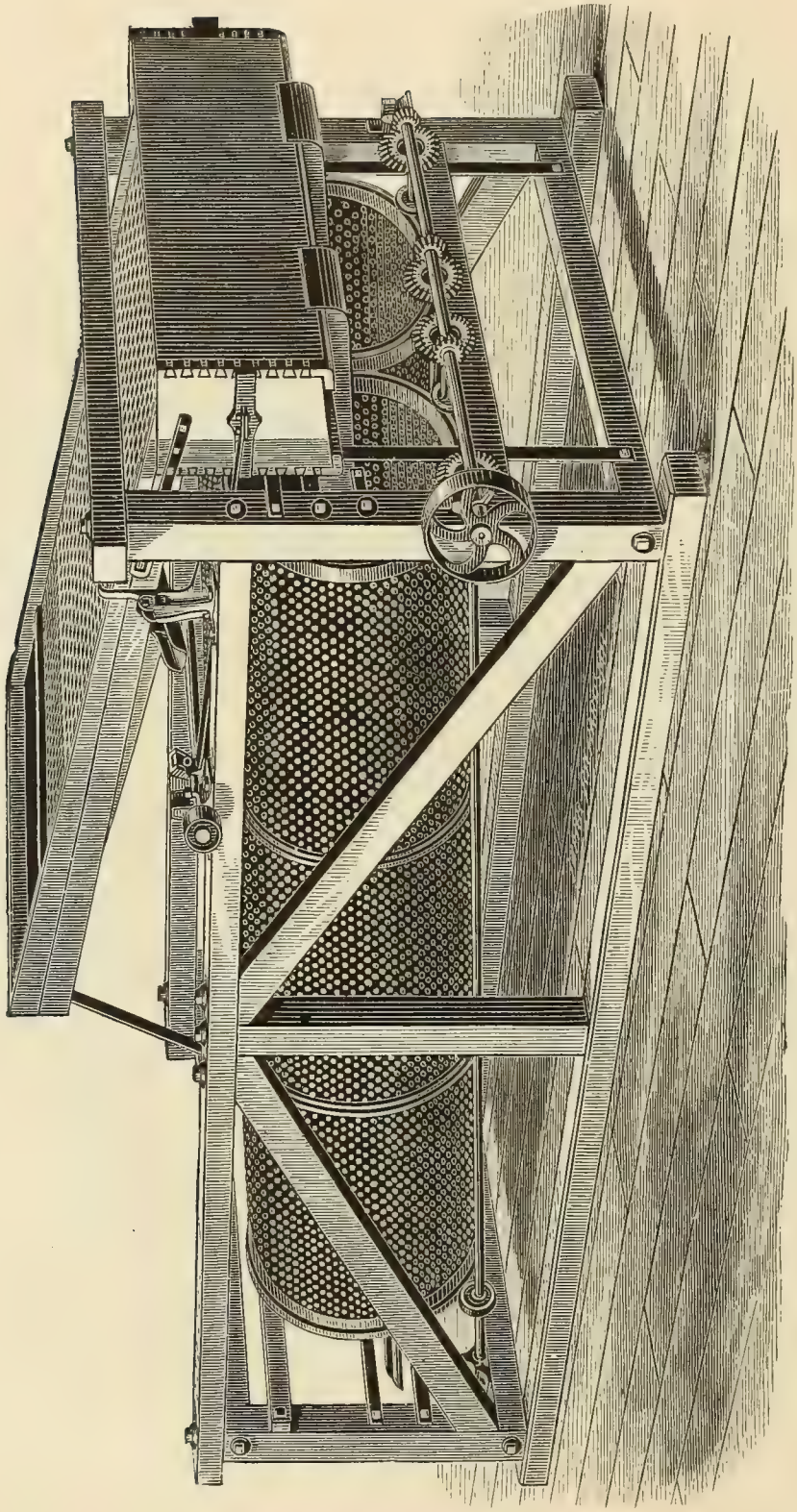


FIG. 160.—DOUBLE CYLINDER COCKLE MACHINE. COCKLE SEPARATOR MANUFACTURING CO., MILWAUKEE, WIS.

the wheat then passes to the centre of the machine and through a series of sieves which take out the oats, etc., after leaving which it passes over a fine sieve extending the entire width of the machine, which removes all the small

FIG. 161.

FIG. 162.

FIG. 163.

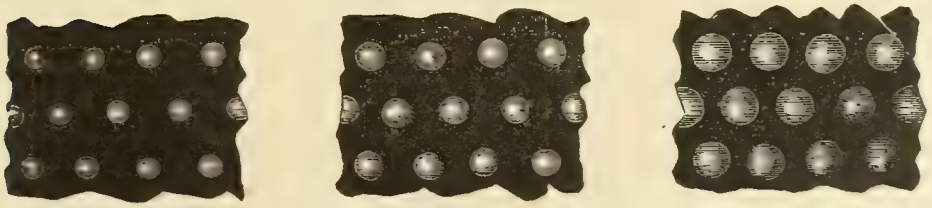


FIG. 164. VARIOUS SIZES OF INDENTATIONS.

seeds, etc. The wheat then enters another suction-spout and undergoes the same process as when first entering the machine. Motion is given to the sieves by a close eccentric, which enables them to run smoothly and steadily without

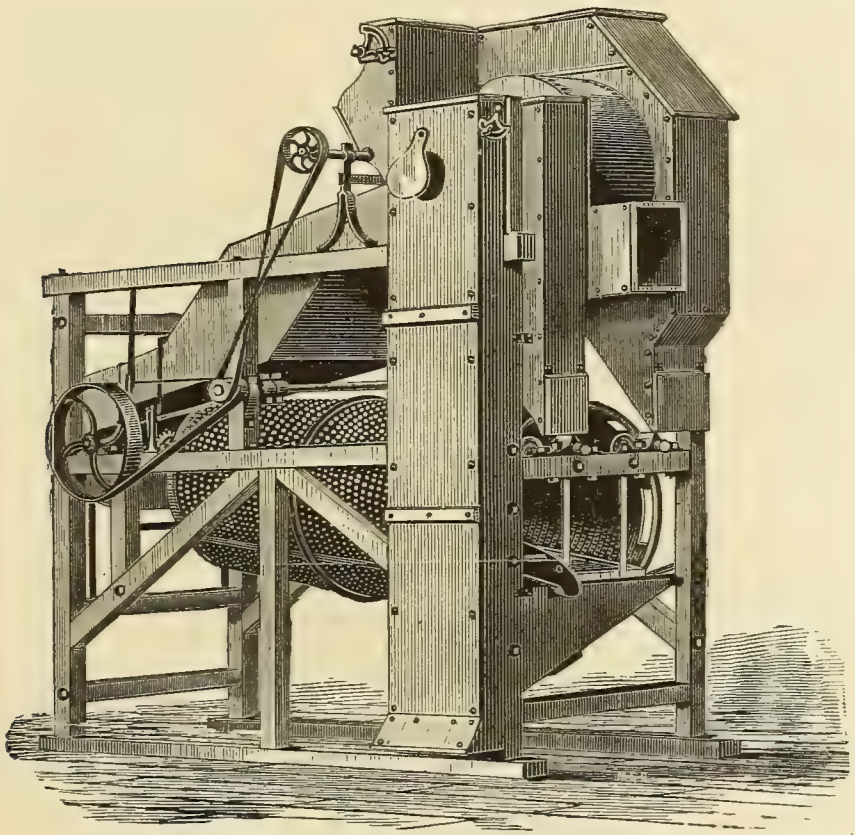


FIG. 165.—COCKLE AND OAT SEPARATOR.

jar, thus causing the oats to pass off while the wheat is shaken through. Each sieve can be cleaned, if necessary, without stopping the running of the machine.

DIMENSIONS, CAPACITY AND PRICE.

STYLE OF MACHINE.	No. of Machine.	Capacity per Hour in Bushels.	Space Occupied, including all Projections.						Height where Wheat Enters.		Driving Pulley.			
			Height.		Length.		Width.				Distance from Floor to Centre.		Diameter.	Face.	Revolutions per Minute.
			Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	In.	In.	
Plain Machine	0	90 to 110	5	10	12	8	5	0	5	10	3	10	8	5	480
	1	60 to 75	4	10	10	4	4	4	4	10	3	1	8	5	480
	2	30 to 40	4	3	9	4	3	11	4	3	2	10	8	5	500
	3	15 to 20	4	3	8	6	4	3	4	3	2	10	8	5	500
Double Deck Plain Machine	0	180 to 200	11	0	12	8	5	0	5 9 & 11	0	3 10 & 9	1	8	5	480
	1	120 to 140	9	4	10	5	4	6	4 9 & 9	4	3 2 & 7	8	8	5	480
Double Parallel Plain Machine	00	110 to 125	5	0	11	6	6	5	5	0	3	8	8	5	480
Four Cylinder Plain Machine	0000	225 to 250	9	2	11	6	6	6	5 0 & 9	2	3 8 & 7	8	8	5	480
Cockle Separator and Oat Separator Combined	00	110 to 125	8	8	12	3	6	6	7	10	6	5	8	5	480
	0	90 to 110	9	2	12	9	5	0	8	4	6	10	8	5	480
	1	60 to 75	8	2	10	10	4	6	7	4	6	0	8	5	480
	2	30 to 40	7	5	10	6	4	0	6	8	5	4	8	5	500
	3	15 to 20	7	5	9	2	4	2	6	8	5	4	8	5	500
Oat Separators	1	100	8	5	5	4	5	10	7	6	6	10	8	4½	500
	2	65	8	0	4	10	5	6	7	0	6	5	8	4½	500
	3	45	7	7	4	8	5	0	6	10	6	2	8	4½	500

In the oat separator the wheat first gets a strong upward current of air regulated by a valve. The screenings are let through at the drop-spout. The chaff and dust are drawn into the fan and blown out of the building. The wheat and oats pass to the centre of the machine, where one series of sieves take out the oats, and a fine sieve the small seeds. Capacities are minimum, and are subject to variation according to nature of grain and impurities and comparative quantity of impurities to be removed.

The following table shows the diameters of the holes of the sizes in perforated screens used for various purposes :

When ordering, give exact sizes of perforations and size of sieve, and, if possible, send sample of what is wanted.

Diameters of sizes used in grain cleaning and for other purposes : $\frac{1}{16}$, $\frac{1}{14}$, $\frac{1}{12}$, $\frac{3}{32}$, $\frac{7}{64}$, $\frac{1}{8}$, $\frac{9}{64}$, $\frac{5}{32}$, $\frac{11}{64}$, $\frac{3}{16}$, $\frac{13}{64}$, $\frac{7}{32}$, $\frac{15}{64}$, $\frac{1}{4}$, $\frac{5}{16}$, $\frac{3}{8}$, $\frac{7}{16}$, $\frac{1}{2}$, $\frac{9}{16}$, $\frac{5}{8}$, $\frac{11}{16}$, $\frac{3}{4}$, $\frac{7}{8}$ and 1 inch.

Size commonly used for small seeds, etc., $\frac{1}{16}$ inch.

Sizes commonly used for flax : $\frac{1}{16}$, $\frac{1}{14}$ and $\frac{1}{12}$ inch.

Sizes commonly used for cockle : $\frac{3}{32}$, $\frac{7}{64}$ and $\frac{1}{8}$.

Sizes commonly used for taking oats from wheat : $\frac{5}{32}$, $\frac{11}{64}$, $\frac{3}{16}$, $\frac{13}{64}$, $\frac{7}{32}$, $\frac{15}{64}$ and $\frac{1}{4}$ inch.

Sizes commonly used for cleaning barley: $\frac{9}{32}$, $\frac{5}{16}$, $\frac{3}{8}$ and $\frac{1}{4}$x$\frac{5}{8}$ and $\frac{3}{16}$x$\frac{3}{4}$ oblong.

Sizes commonly used for receiving riddles : $\frac{5}{16}$, $\frac{3}{8}$ and $\frac{7}{16}$ inch.

Sizes commonly used for corn screens : $\frac{1}{2}$, $\frac{9}{16}$, $\frac{5}{8}$, $\frac{11}{16}$, $\frac{3}{4}$ and $\frac{3}{8}$x$\frac{5}{8}$ and $\frac{1}{2}$x$\frac{3}{4}$ oval.

In stock, $\frac{1}{16}$, $\frac{3}{32}$, $\frac{1}{8}$, $\frac{5}{36}$, $\frac{3}{16}$, $\frac{7}{32}$, $\frac{1}{4}$, $\frac{5}{16}$, $\frac{3}{8}$, $\frac{7}{66}$, $\frac{1}{2}$, $\frac{5}{8}$, of No. 11 zinc.

Grader and Dustless Separator.—In Fig. 166 is shown a machine which is thought to combine all of the points essential to the successful working of a dustless receiving separator. The main points considered in its construction have been strength and simplicity. Other essential points of excellence are as follows : 1. Very little room is taken up by the machine. 2. So little power is required to run it that it is scarcely noticeable, having no heavy eccentric springs, and being run at a much lower speed than most machines of its class. 3. The separations are independent of each other, and are completely under the control of the operator. 4. The convenience with which all the bearings of the machine can be oiled is a noticeable feature. 5. The fan-blast can be increased to suit long spouting without interfering with separations or the working of the shoe. 6. The throw of the shoe can be shortened or lengthened as required while the machine is in motion. 7. The screen can be changed while the machine is in motion.*

Size.	Extreme Height.	Height when Wheat enters.	Size on Floor.	Size over All.	Diameter Pulley.	Face of Pulley.	Motion per Minute.	Capacity in Bushels per hour.	
								Wheat.	Barley.
0	5 ft. 6″	5 ft. 3″	32 × 32″	4 ft. 3″	7″	4½″	425	25 to 40	
1	6 ft.	5 ft. 6″	34 × 34″	4 ft. 6″	7″	4½″	425	40 to 60	100 to 150
2	6 ft. 6″	6 ft. 3″	36 × 36″	4 ft. 9″	8″	5″	425	60 to 100	200 to 250
3	6 ft. 9″	6 ft. 6″	38 × 38″	5 ft. 3″	8″	5½″	400	100 to 150	300 to 400
4	7 ft.	6 ft. 9″	40 × 40″	5 ft. 6″	9″	6″	400	150 to 200	450 to 550

* Simpson & Gault Mfg. Co., Cincinnati, O.

Smutter and Separator.—The Champion Smutter and Separator,* Fig. 167, is a vertical machine, driven with only one pulley. It is illustrated in section. The wheat enters the suck-spout A, where it passes through a current of air which removes from the wheat all straw, chaff or other light substances that would incline to choke and obstruct the work of the riddle. It then enters the riddle B, where the sticks, nails, oats, and cockle are removed. From the cockle-riddle it passes into the spout C, in a broad,

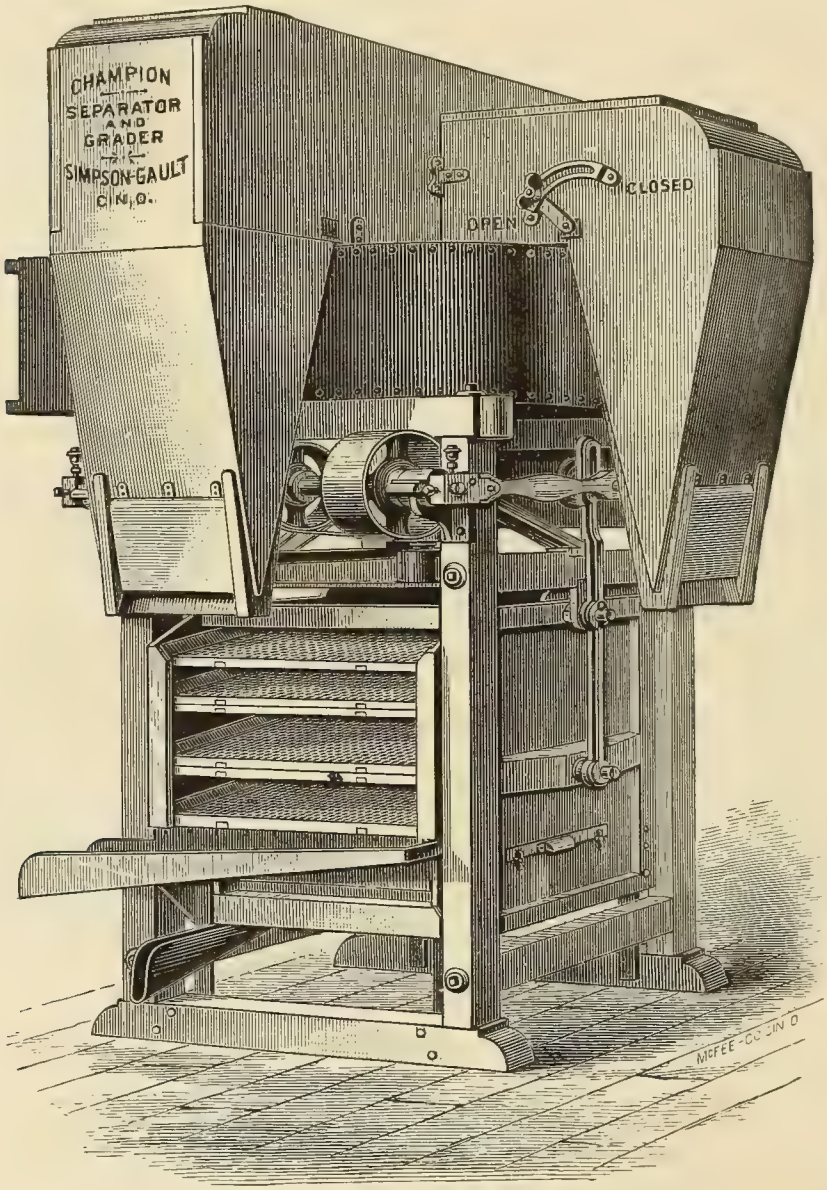


FIG. 166.—"CHAMPION" GRADER AND DUSTLESS SEPARATOR.

thin stream. This spout is very wide, causing the wheat to enter at the full width of the cockle riddle quite gently, in so thin a stream that the air can penetrate and operate upon it in the most thorough and perfect manner. The shoe is operated by an eccentric at D, receiving a short endwise motion. The grain, leaving the lower perforated end of the spout C, falls into an incline trough, and is carried into the scouring-case. This consists of a

* Made by the Simpson & Gault Mfg. Co., Cincinnati, O.

hollow iron cylinder, to the surface of which are attached vertical beater bars. The cylinder is secured to the main shaft and revolves with it. Outside of this beater-cylinder is the stationary perforated steel jacket, and again outside of the jacket in the upward flaring sheet-iron case H.

The grain enters between the beater-cylinder and the perforated jacket, passes downward and out at the bottom of the case, and into the long discharge spout shown in the perspective view of the machine. While in the scouring case it is met by a strong upward current, procured by the motion of the fan, and fed from without through the air-tubes, E. The current passes

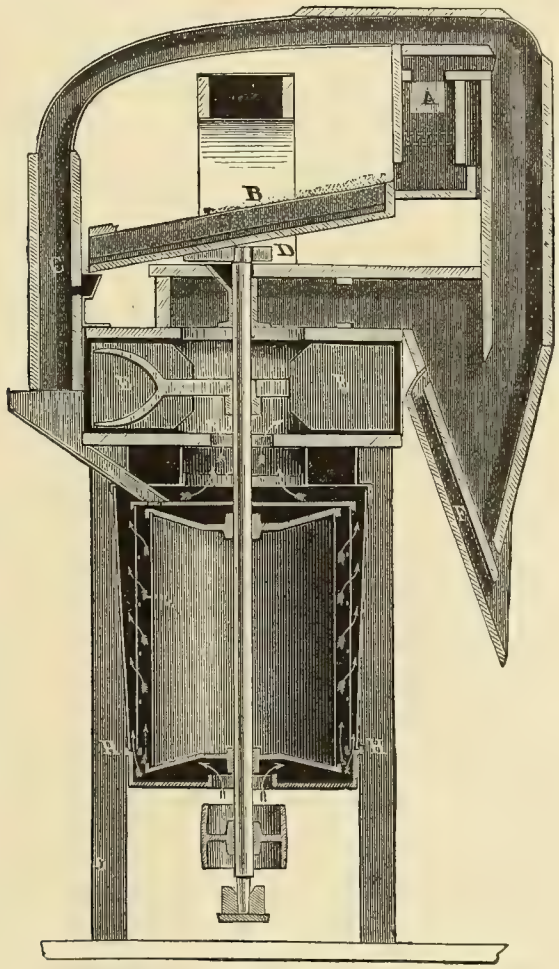


FIG. 167.—SECTION OF CHAMPION SMUTTER AND SEPARATOR.

down through the interior of the beater-cylinder, and returns upward between the cylinder and the outer case (and both sides of the perforated jacket), *holding the wheat suspended* while undergoing the process of scouring, and carrying off through the fan-case all the dust produced by that operation. The action of the fan also produces an upward current in the large discharge spout which effects the second separation by carrying the lighter particles upward and over to the opposite side of the machine, where they are again met by a reverse current through the air passage F. Both spouts are constructed alike in this respect, and the offal falling through this upward current in each case is divested of chaff, dust, &c., and leaves the machine ready for grinding.

Thus there are four separations effected. It is claimed by the makers: That the small, imperfect, or broken grains that may be driven through the perforations of the jacket, are saved in a clean condition, valuable, and fit for seed. They will fall down through the perforated cast-iron ring (which sustains the jacket), on to the closed bottom below the ring, be discharged with the wheat through the air current in suck-spout, and carried up and over, and be discharged through the trap-door (see cut). In many other machines such particles are either driven out in the fan-discharge and lost, or thrown down upon the floor through the open bottom. This machine seems to be specially liked as a barley and rye separator and cleaner.

In setting up the "Champion" Smut Mill, pay particular attention to the directions, which may be found pasted upon each machine.

Select your location; see that the openings to all the spouts are unobstructed; give the machine the proper speed with the proper feed; regulate the valves till the offal is right, and the results will be sure and satisfactory. To do good work, a smut machine (like a man) must have good, strong lungs and plenty of air.

Direction for Setting Up and Running the Champion Smut and Separating Machine.—1st. Level the machine by the frame, and see that the joint bolts are screwed up. 2d. Secure the machine firmly in place on the floor. 3d. Place the upper spout in position, as shown in the cut and indicated by the screw holes. The necessary screws will be found in boxing. 4th. Place the upper spout and secure as above. 5th. Put the shaker in its place on the top of the eccentric, and screw down the nuts on the springs at the sides and lower end of shaker. 6th. Brace the upper part of the frame against the motion of the shaker. 7th. Give the machine the revolutions per minute indicated in the table, and be particular to maintain that velocity. 8th. When automatic valves are used, to regulate the current of air in suck-spout, turn up the thumb-screws on the self-acting valves. Increasing the tension will give stronger current and heavier offal. 9th. Use lard oil and lard and blacklead for the eccentric. The machine can be oiled in motion. 10th. Do not cut off or inclose the mouth of the long discharge-spout, as there must be a free inward air-current. 11th. When the dust-spout is used to convey the dust out of the mill or to the dust-room, it should be at no place smaller than the fan-discharge, and when crooks are made they should be on a circle, and not a less circle than the circumference of the fan. The screens in this machine are adapted to the general demand.

No. of Machine.	Extreme Height.	Height where Wheat enters.	Size on Floor.	Diam. of Pulley.	Face of Pulley.	Motion per Minute.	Height from Floor to centre of Pulley.	Smallest Capacity per hour.
0	6 ft. 5 in.	5 ft. 7 in.	25 × 25 in.	7 in.	4½ in.	700	9 in.	15 bus.
1	7 ft. 3 in.	6 ft. 4 in.	28 × 28 in.	8 in.	5 in.	650	10½ in.	30 bus.
2	7 ft. 6 in.	6 ft. 6 in.	30 × 30 in.	9 in.	6 in	600	12 in	50 bus.
3	9 ft.	7 ft. 6 in.	33 × 33 in.	10 in.	7 in.	550	13 in.	80 bus.

Wheat Brush.—In the Champion Wheat Brush,* Fig. 168, there is a hand wheel and lighter burr, by means of which the machine may be made to brush hard or light, as desired. There is a steel perforated case from the brushes to work against, the same as in the Champion Smutter.

We have had prepared the following table showing the pulley diameter and width, number of revolutions per minute, height of centre of pulley, capacity per hour in bushels of wheat and barley, weight ready to ship, size on floor, life of screens, brushes, etc., of the Champion Combined Separator and Smutter, Brush and Separator. "The wheat is fed

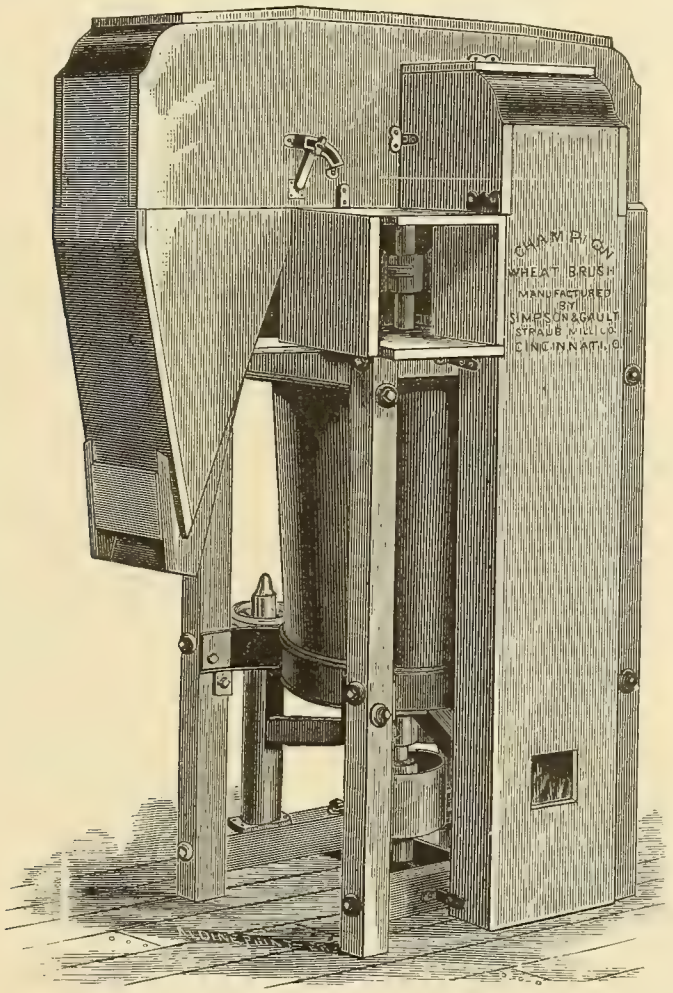


FIG. 168.—CHAMPION WHEAT BRUSH.

into a hopper, so arranged that it can be placed at either side of the machine, into which the wheat can be spouted from any direction. From the hopper the wheat passes into the separating trunk through a strong current of air, where all light stuff can be drawn off. It is then spouted into the machine, and falling upon the centre of the concave cylinder head is distributed equally around and against the perforated case. It is here met with a strong upward current of air, which in conjunction with the rings on the case will hold the grain long enough to do all the brushing required. In leaving the machine, the wheat passes through another strong current of air

*Simpson & Gault Mfg. Co., Cincinnati, O.

in the discharge spout, taking out all remaining dust, and leaving it polished, ready for the stones. The machine can be oiled while in motion. As the bearings are iron bridge trees, with babbitt-metal boxes, and isolated from the wood, it is absolutely free from danger of fire."

Size.	Extreme Height.	Height Wheat enters.	Size on Floor.	Diameter of Pulley.	Face of Pulley.	Motion per Minute.	Capacity per Hour.	To Centre of Pulley.
1	6 ft. 3 in.	5 ft. 6 in.	28 × 28 in.	9	5	500	30	10 in.
2	6 ft. 6 in.	6 ft.	30 × 30 in.	10	6	450	50	10 in.
3	6 ft. 6 in.	6 ft. 6 in.	33 × 33 in.	10	6	400	80	11 in.

CHAPTER XX.

WHEAT DRYING AND HEATING.

Drying Wheat—Heating Wheats—Generators for Wheat Heaters in Water Mills—Thermometer Attachment for Wheat Heaters.

Drying Wheat.—It is essential that flour which is to be sent abroad should be thoroughly dried, if it is to be kept in good condition. It is not quantity but quality which causes the miller the most anxiety. The miller's art consists in blending different kinds of wheat coming from different parts of the country, and possessing individual qualities, so as to produce the best results. Wheat ripened under the hot southern sun is more brittle and contains less water than that grown out west, and American wheat is from ten to twelve per cent. dryer than European wheat. If the wheat is not properly prepared, loss of flour is entailed.

The bran of dry wheat, from its extreme brittleness, is apt to break up fine and discolor the flour; so the miller frequently sprinkles it to soften the bran and reduce its brittleness. If, now, instead of doing this, he would heat his wheat, the moisture still remaining might, by vaporizing, be utilized to soften the bran, and prevent it from mixing with and discoloring the flour.

Heating Wheats.—It often happens that the best flour is made during the hottest months, as the summer heat dries the moisture out of the kernel into the husk. The wheat heater permits the miller to get a uniform grade of flour the whole year round, and causes the bran to come off as nearly a whole shuck as possible. Hard, flinty or dried wheats especially need heating, as their bran is always brittle. Less power is required for grinding heated than unheated grain. Hard and soft wheat mixed together are better blended by heating than by any other means. If wheat, after being hot, loses its heat, it becomes more brittle. The skin is tough only so long at it is hot. Overheating by allowing the feed to be shut off without shutting off the steam in the heater, causes the wheat in the latter to be gummy and to start feeding with difficulty. It is not necessary to have a heater for each run of stone.

In putting the wheat heater in place, cut in a plank a round hole the diameter of the inside of the hopper, fasten this plank to where you wish to bring the wheat from the stock hopper, bolt the hopper to this plank, or fasten it to the floor if convenient, and make your connection with the steam pipes as direct as possible. Be sure to use a large enough pipe. Three globe valves will be required, one on the boiler and one each for supply and exhaust. These supply and exhaust valves should be so placed that the miller can stand on the floor and handle them. The exhaust should be wide open to let the exhaust steam blow out when steam is turned on, and then it

should be closed so as barely to let the condensed steam run out. Whenever the mill is stopped the steam supply of the heater should be shut off and the exhaust opened. This prevents the wheat standing in the heater from becoming superheated and gummy. To make a first-class flour to stand a sea voyage, the wheat must be dried.

The heater is, in the opinion of some millers, good to use with rolls in the winter where the wheat is frozen. In most mills the temperature of the wheat

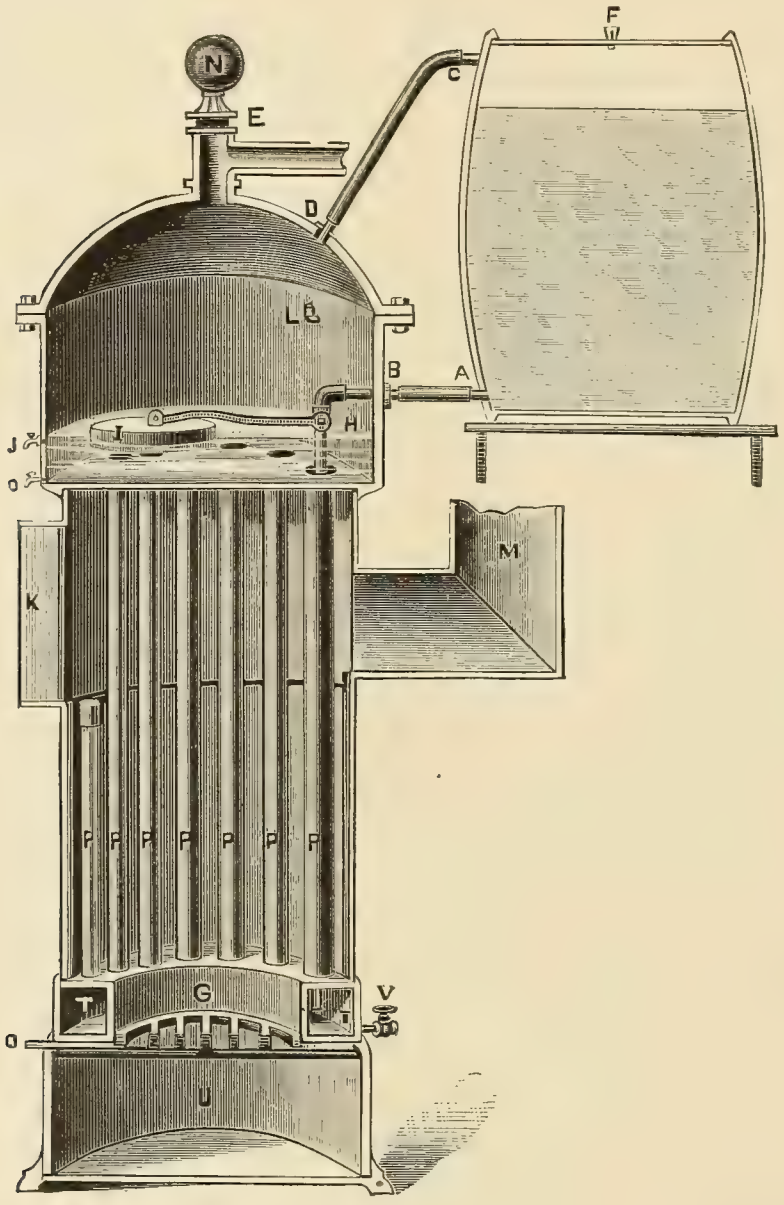


FIG. 169.—RICE'S STEAM GENERATOR FOR WHEAT HEATERS.

as given by the heater, is guessed at, whereas there should be a thermometer to indicate exactly what the temperature is. As regards dampening the wheat, it is all wrong, because there is already enough moisture to toughen the grain in passing through the wheat heater, and as it is desirable to have the chops as dry as possible. Every particle of water added as water or as

steam will cause damp grinding. Dampening by steam or by water is prevalent in the Western and Southern States.

While English wheat generally contains enough moisture in itself to toughen the bran when heated, many others require to be dampened.

One trouble sometimes experienced is in the use of heaters for gradual roller reduction. It is found that after the first break (during which the bran is preserved in good shape) it becomes so dry that it pulverizes even worse than if the heater were not used.

No tobacco grower would be foolish enough to undertake to manufacture his material without first preparing it so that it may work to best advantage. Yet there are many millers who manufacture their raw material just in the state received, whereas it needs drying or heating. This simply makes the good conditions of June and July continue all the year round.

There are many excellent wheat heaters in the market; the writer is not prepared to say which is the best. Welch's, Gratiot's, and the Star have a large sale.

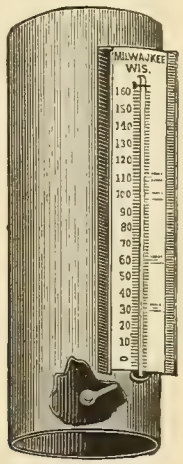


FIG. 170.

Generators for Wheat Heating.—There are many water mills which would put in steam wheat heaters if they had any means of generating the small quantity of steam to supply the heater. To meet this demand there is offered by C. B. Rice & Co., No. 218 E. Washington street, Chicago, an ingenious device requiring little attention.

Fig. 169 shows a vertical lengthwise section of this generator. The fire is built on the grate G, and the gases of combustion pass up among the water tubes P, which connect the upper and lower spaces of the shell. The water is introduced from the tank through a pipe, B, and when it reaches the proper level, the float I rises and cuts off the supply. Equilibrium is maintained between the tank and the boiler by means of the pipe C. The steam passes through the pipe E to the heater. N is a simple form of safety valve. K is the fire door and M the smoke passage. The generator has the proper blow-off and gauge-cocks. There are two sizes made, standing 48 and 52 inches in height, and weighing 280 and 375 lbs. respectively. A number of these

are in use in water mills as well as for steaming feed and other farm purposes.

Thermometer Attachment for Wheat Heaters.—The problem of measuring to a fine nicety the degree to which the grain is heated has been very successfully solved by a thermometer* attachment, Fig. 170, adapted for any wheat heater. The idea is to place the thermometer in such a position that it shall not be affected by external temperature, but, at the same time, shall be capable of indicating the changes in temperature of the heated grain. This has been accomplished by attaching a thermometer, with an accurately graduated scale, to the discharge pipe of the heater. The thermometer tube is bent and penetrates the discharge pipe at an angle of about 135°. By bending the tube in this manner the bulb is brought into a central position in the discharge pipe, and wholly surrounded by the grain as it comes directly from the heater, registering therefore with great accuracy the temperature to which the wheat is heated.

* Made by W. N. Durant, Milwaukee, Wis.

CHAPTER XXI.

GRANULATION AND GRINDING.

General Classification of Granulating and Grinding Devices — Disc Milling — Material of Discs — Burr Millstones — Oscillating Upper-Runner Horizontal Mill — Oscillating Under-Runner Horizontal Mill — Rigid Runner Horizontal Mills — Under-Runners — Vertical Mills — Iron Discs — Iron Cones — Methods of Driving Rolls — Cylindrical Rollers — Single Roller Working against a Curved Face — Materials of Rollers — Surface of Rollers — Grooved Chilled Iron Rolls — Smoothed Chilled Iron Rolls — Smooth Porcelain Biscuit Rolls.

Granulation and Grinding.*—The question of granulation or grinding is one having so many divisions and subdivisions that its treatment alone could be made to fill a volume of considerable size. The double title, "granulation and grinding," is used because these two operations, while not exactly the same, have an intimate connection, and may be effected upon the same machinery with but slight changes therein. We may state, as the difference between granulation and grinding, that grinding may be considered as reducing to powder, and granulation reducing to grains. This difference may be caviled at by some, but in any case it is a distinction that we are going to make and adhere to for the purpose of clearness and preciseness

The first broad distinction that may be made would be into disc, roller, beater and blast machines; the most generally used being the first-named. The first might be called plane milling and the second convex, because in the first the reduction is done between plane surfaces only, and in the second it is done between a convex and an opposing surface. In disc milling both grinding surfaces are always in opposition. In roller milling there are two styles, one in which a single roller works against a concave, and in this one of the opposing surfaces is always in opposition and the other changes. Where there are two rollers working together, there is but a line of each surface in contact, and this changes constantly. In the beater machines, projecting pins, in rapidly-revolving cylindrical cages, reduce the material by a succession of blows against the beater pins, the walls of the chambers, and against each other. In blast machines, of which there are only a few in use, a powerful blast of compressed air is used to drive the material between the roughened walls of the two fan-shaped plates placed closely together.

There are employed in granulation and grinding the following devices: burr millstones, with either upper, under, or vertical runners, and either rigid

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* It having been urged by a practical miller, to whom was intrusted the task of criticising the manuscript of such portions of this work as refer solely to milling matters, that it was "as absurd to describe a mill to a miller as it would be to describe a case to a compositor or an oven to a baker," the writer begs to say that in the professions of engineering, architecture, etc., the classifications and descriptions in text-books and works of reference are found to be of special value, and the more thoroughly posted a professional or a practical man in those professions may be, the more highly detailed classification, descriptions and specifications are appreciated.

or oscillating; roughened or corrugated iron discs; roughened or corrugated iron cones, working in concaves; rollers of porcelain, stone, smooth and corrugated iron and steel, all singly or in pairs, with equal or with differential motion;* and percussion or attrition machines. Some of these exist in great variety; and with each of them the miller has his choice of a number of processes and variations thereof. We shall describe each of these in detail under a separate heading, and also treat the processes separately.

A German maker is experimenting with porcelain block discs, the use of which appears plausible, and even glass millstones are seriously proposed. Since writing the above, conical rolls are advocated.

Disc Milling.—In disc milling there are two discs with their axes in the same line, and their flat faces in opposition.† The axes are generally horizontal, although in small sizes they are vertical. The material employed is generally burr-stone, although there are used other kinds of stones, and also porcelain and glass blocks, cast iron, etc. In those mills having vertical axes the upper stone is usually the runner, the lower or bed being stationary, although there are many mills in which the under stone is the runner, the upper one being stationary; and in one experiment both stones were made to revolve in opposite directions.

The axis of the runner is generally adjustable lengthwise, to regulate the distance between the two stones, and also in a plane parallel with the disc face and in every direction, so that two faces may be placed and kept in exact parallelism. In upper-runner mills the spindle of the runner always passes through a suitable eye in the bed-stone. In under-runners there is no need of an eye in the runner. Vertical mills correspond to under-runners in that the spindle of the runner does not pass through the stationary stone.

There are two ways of driving the runner. One is that by which the driver is rigidly attached to the runner, and exact parallelism of disc faces is secured and maintained by the accuracy with which the spindle is placed exactly in the centre of and at right angles to the disc. Such a driver is called a stiff driver, and the runner is called a rigid runner. In the other and the more prevalent type the runner is mounted upon a pivot upon the upper end of the spindle by means of a cross piece or bail bridging across the eye, and which engages with the horns of a forked driver attached to the end of the spindle. This is called a balanced runner or oscillating runner. In it the runner is permitted to accommodate itself in parallelism to the stationary disc. In vertical disc mills we find sometimes the stationary stone adjustable instead of the runner.

Material of Discs.—Having spoken of the method of mounting the discs we will next consider the material of which they are made. The most common is burr-stone, generally from La Ferté-sous-Jouarre, France.‡ There

* Prof. W. D. Marks calls the author's attention, as this chapter goes to press, to the advantages of hyperbolic rolls, which are of a form generated by a "hyperboloid of revolution," instead of by a rectangle, which generates a cylinder.

† There are also mills in which there are three stones—the central one double-faced, and revolving between two stationary stones in the same line; the axis being horizontal. A still further variety has two discs, set eccentrically one above the other; the axes vertical and parallel; either or both discs rotating.

‡ See Chapter XXII.—Burr-stones.

are also Esopus, Cologne, and Peninsula stone, granite, with other stones, though employed very little. Discs made up of blocks of porcelain, biscuit, and of glass blocks have been tried, but we have no record of their performance. Cast-iron discs have long been employed for the rougher milling reduction, such as corn grinding, but they are now coming into use for the most delicate reductions of the later and more complicated milling systems. It will be seen that under the head of discs we have a large variety of material, and a still greater number of combinations of methods of mountings, as either the upper-runner, the under-runner, or the disc with horizontal axis, may have either stiff or balanced drive.

Burr Millstones.—The burr-stones of disc shape are the oldest and most extensively employed means of granulating. The materials we describe in full in Chapter XXII., the mounting and running in Chapter XXIII., and the mode of dressing in Chapter XXIV. It remains to compare here the various classes of mills—upper and under runner, rigid and oscillating.

Oscillating Upper-Runner Horizontal Mill.—This is the oldest and best known. It consists essentially of a fixed circular-faced level bedstone, through which passes a revolving spindle, on which as a pivot is balanced a heavy runner hung at a point a little above its centre of gravity on an iron cross piece or bail, which engages with the horns of a driver revolving with the spindle. Through the large opening or eye of the upper revolving stone the feed falls upon a fixed or dead surface, from either a hopper or a silent feeder. In the first case the hopper has a "shoe," which is generally sharply vibrated by a damsel.*

The detailed instructions in Chapter XXIII. are for mounting upper-runner mills.

In these mills the pressure, and hence the fineness of grinding, is to a certain extent given by the weight of the runner, usually very considerable, although the lighter screw is used to govern it somewhat.

Oscillating Under-Runner Horizontal Mill.—In this the upper stone is fixed and the lower one rotates, the feed thus falling upon a rotating or "live" surface. The fineness of grinding is governed solely by the distance of the burrs as regulated by the lighter screw, the weight of neither stone influencing it.

In both the above the runner is hung on a pivot so as to be capable of changing its plane. It is a most difficult and delicate adjustment, requiring the highest mechanical skill to make and maintain.

Rigid Runner Horizontal Mills.—Mills of this class are coming more generally into use, especially for middlings' grinding and for "ending" grain, and depend for the uniformity of granulation upon the absolute accuracy and rigidity of the stone and of the spindle.

Under-Runners.—The under-runners can be driven much faster than the upper. They also permit getting the grain into the bosom with a very small eye, and thus grind nearer the centre than upper-runner mills can. They are less liable to choke, and run better than upper-runners do when

* Also written "dansil."

belted to an irregular power, as a saw-mill engine, the motion of which is very irregular.

Vertical Mills.—These are generally small. They depend in almost all cases on pressure for the fineness of grinding. They, too, are either rigid or oscillating. The feed is different, and often assisted by a screw.

Iron Discs.—The grinding surfaces of iron discs are generally chilled, either wholly or in part, and are used both for rough grinding, as for feed, and for fine granulation.

Iron Cones.—Iron cones working in a conical case are used by millers only for rough feed grinding, although very common for drug, bark and paint grinding. They engender much heat, and, because of the great frictional resistance of the grinding surfaces, take great power to drive them.

Methods of Driving Rolls.—Rolls, as we have before said, may work either singly, against fixed breasts or concaves, or against moving rolls. Working together, they may be arranged one above the other, or side by side, the latter being the most usual, except in those cases where there are three rolls, one above another, the middle one in contact with the upper and lower ones. Whether arranged one above another or side by side, rolls may divided into three classes as regards the motion received. In some, one roll is driven by positive means, and the other driven by friction from the first one. In others, both rolls are positively driven, and both at the same rate of speed. In the third class, both rolls are positively driven, but one is driven faster than the other.

There is a still further method of driving in which one roll drives the other by friction. Of course the two revolve in opposite directions. In others, they both revolve in the same direction, that is, where the reduction takes place, one surface runs in one direction and the other in the other.

As regards the application of power for driving rolls, the most common ways are by spur gears and by belts. Friction wheels and link belts have been proposed, but are not yet in ordinary use.

Cylindrical Rollers are used in pairs,* and with equal speeds have a nipping or crushing action. Used with differential speeds they have a cutting or shearing action, more nearly approaching that of millstones than the cracking of equally speeded roller-pairs.

Single Roller Acting against a Curved Face.—This has the effect of the differently-speeded rolls, but the contact is a surface, as with burrs, and not a line, as in roller-pairs.

Materials of Rollers.—As regards the materials employed, we find stone, steel or chilled iron and biscuit (miscalled porcelain). Some grades of stone have a natural gritty or cutting substance, and these are generally dressed smooth, but not polished, for granulation, although in one case, where a single roller is used, rubbing against a concave stone breast, longitudinal recesses, like furrows, are made, to facilitate feed and reduce heating, and possibly otherwise influence the grinding.

Surface of Rolls.—Chilled cast iron and steel are sometimes smooth-surfaced when simply for sizing middlings or flattening germs, but are gen-

* In three high rolls the principle is that of the roller pairs, the central roll acting as a member of two pairs.

erally grooved either straight or spirally, generally the latter. Steel is but little used.

The size, pitch, sharpness, &c., of the grooves and the difference of the speeds largely influences the output of the mill, and should be carefully chosen with reference to the special work to be performed.

Grooved Chilled Iron Rolls.—Grooved, fluted, corrugated, or rifled rolls are made of the best cast iron thoroughly chilled and then either grooved straight or rifled by special machinery. The grooves are in all cases parallel to each other, but generally run spirally with a twist around the roll, and in some cases have very decided and sharp edges of the same outlines as the teeth of a hand rip-saw, while in others they have rounded edges.

Smooth Chilled Iron Rolls.—Chilled iron rolls with smooth surfaces are used for crushing wheat, sizing or reducing middlings, and rolling coarse middlings and tailings in order to extract the germs of the bran specks. They give the best results as to quantity and quality after they have been in use a few months to work off their initial smoothness of finish.

Smooth Porcelain Biscuit Rolls.—The smooth biscuit or so-called porcelain rolls have many advantages over chilled iron or steel, especially in the reduction of middlings into flour. The reason of this is that the chilled iron soon becomes smooth and glassy, having less grip or grinding quality than when new and requiring more power. The unpolished porcelain roll has a dull, velvety surface, with a capacity of adhesion which enables it to act upon the smallest particles of flour and to separate them. It is said, too, that chilled iron discolors the flour, making it bluish or gray.* The porcelain biscuit is said to be so hard that nothing but the diamond will cut it, although the writer has not been able to verify this statement, and doubts it. It is indifferent to all chemical influences, and has no tendency to cake the crushed meal, especially with the middlings and tailings of soft winter wheat. Porcelain rolls feed the easiest. There is said to be over 6,000 porcelain rolls in use in this country and in Europe.

CHAPTER XXII.

THE BURR-STONE.

Various Stones used for Grinding—Burr-stone Proper—La-Ferté-sous-Jouarre—Ordinary Millstones.

Materials of Millstones.—There are employed for milling purposes, sandstone, granite, basalt, lava, porphyry, and burr-stone proper.

The quartz sandstone of Perg, in Upper Austria, is much used for rye milling. It works better on dry than on moistened grain. Can be used for either breaking or flouring.

The millstone of Tilleda, in the Kyffhauser, is a sharp, open, red sandstone, suitable for either breaking or flouring.

The Münden stone is a white, sharp, fine porous sandstone, used in north Germany on rye. By reason of its grindstone-like action, it is generally used working against Crawinkler stone.

The Jonsdorfer stone is like the Münden. It is found near Zittan, and used in Bohemia in large runs for hulling and in small ones for rye grinding.

Rhine stone (lava or basalt,) comes from Andernach, is of a dark, grayish blue color, very porous, and was once much demanded for wheat milling. This stone is not too hard, and dresses easily and sharply. Somewhat like it is the stone from Volvic, in Auverge.

The Crawinkler and Ohrdruffer quartz porphyries, come in very hard but porous masses. The harder are used for wheat, and the softer on rye. The color is gray, sprinkled with felspar crystals.

The Perg quartz granite is very hard and durable, but has not the sharpness of pores peculiar to the French burr-stone.

The trachyte quarries of Hungary have been worked for 800 years. The ancient Sarosptaker quarries yield good burr for low middlings. Sardinia and Germany also have quarries. There is a quarry of valuable material in Randolph County, W. Va., near the great Cheat Mountain limestone belt, sixty miles south of Grafton. This stone is pronounced good for flour and corn, and unusually hard. There is also burr-stone in Georgia.

Esopus stones, from Ulster County, N. Y., are good for corn or oats, making soft pleasant meal for family use. They do not keep their edge long. Stones are sometimes made with a sandstone heart and a burr skirt, and cracked about eight inches from the skirt inward. Such stones will cut up the bran. Granite would make a better heart than sandstone.

Burr-stone Proper.—Burr-stone occurs in the uppermost stratum of the globe. Its texture is cellular, the cells being irregular in number, shape and size, and often closed by fine flakes, or by cross fibres of silex. Its fracture is straight. It is about as hard as flint, but not so brittle, and it

varies from the most open to the closest texture possible. It is sometimes filled with shells or with impressions of vegetable matter.

The stones are cut out by a series of iron and wooden wedges, gradually and equally inserted. For commercial purposes they are made into solid stones, blocks, quarters, panels and half panels. The blocks weigh from 75 to 100 pounds in the rough, the large size measuring in the rough 12 × 20 inches, the small size 14 × 8 inches. They should be dried and seasoned for one or two years. Every block should be tested with a pick for temper and texture. It takes long experience to judge correctly the different qualities of burr.

Some blocks come as small as four inches square, and some as large as twenty-four inches on a side. The Epernon stone (more commonly known as new stock) is found as large as six feet in diameter. While the usual rules for judging the quality of a burr-stone by the color will be found useful, they are by no means invariable.

The quality of the burr-stones varies with the depth from which they are taken. The clear white or variegated stone, resembling marble, is often thought among the best for all uses, being free and hard, and holding an edge well. For corn, the stone with a pale bluish cast is chosen, being of a keener temper and not so subject to soft open places.* It resists the pick more than any other, but once dressed proves the best for hard grain. This burr is not recommended for wheat, as if allowed to get smooth it is apt to heat and to grind wheat oily. If dressed at all rough it will make specky flour and grind harsh. The cream, light gray and drab stones are among the best. Dark or lead-colored stock is vitreous, glazing soon and heating the chop. In the genuine anchor "R" blocks there are about twelve different kinds as regards color, texture and openings. Anchor "R" blocks are sharp, close and hard. In anchor "R" edge blocks the grain runs from face to back. They are of different colors, white, yellow and gray. "W" blocks are medium open, yellow and gray color, medium hard, fine grain. "S" blocks are large, a little more sandy than anchor "R" and "W," and have a white, yellow and violet color. "B" are of inferior quality, coarse grain and dark. "A" blocks resemble anchor "R," being, however, a little more gray in color.

New stock blocks are flinty, very sharp, and will almost cut glass. Edge blocks are the best grinders for wheat. In these the grain runs straight through. They do not require to be cracked often as they keep sharp naturally.

The old stock is considered the best for wheat, being more porous than the new; but there is very little of it left, and old stock burrs are in consequence much dearer than the new.

For wheat and middlings close texture old stock is preferred. New quarry or new stock is generally preferred for corn.

Rye takes a softer stone than wheat does.

A good millstone is told by its even grit, even texture, even openings, even color, and above all by its close resemblance to one solid piece of stone with the joints hardly distinguishable. The blocks should be joined the entire depth and not simply with a face joint.

* Kick considers the bluish-white burr the best, next the yellow, then the reddish, and last the white.

Good workmanship will insure close joints from the face to the back The burrs made by the Simpson & Gault Manufacturing Company are claimed to carry out this principle. Figs. 171 and 172 show the right and wrong way of making joints.

Where one selects his own burrs, it is best to choose a block of the desired quality, and to demand that the rest shall be the same in every particular. A stone of part soft and part hard blocks will not grind well and cannot be kept in good face.

If possible, have all the blocks run from eye to skirt, and in any case have all the joints made close. No matter what material is chosen, the stone should be built up of blocks of equal hardness and porosity throughout, and as far as possible of the same size on similar parts of the stone. In the runner the blocks should be of the same height or thickness. French-built

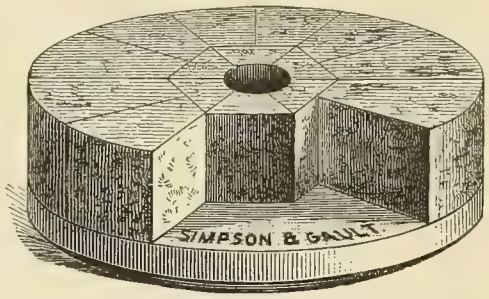

FIG. 171.—RIGHT WAY.

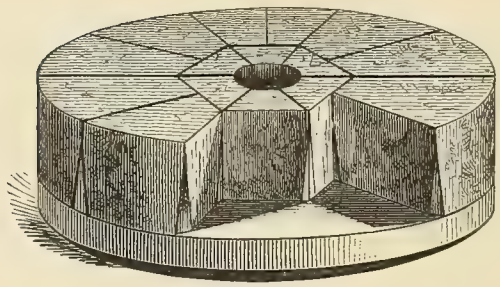

FIG. 172.—WRONG WAY.

burrs are apt to be deficient in workmanship and in selection of stock. "Cask" millstones are built of blocks, fitted and numbered at the quarry with a view simply not to waste stock, and without any consideration for the quality of the stone.

Burr-stone cement is used in the joints, plaster-of-paris in the back. The cement is partly composed of pulverized burr stone. This cement will stand wheat and middlings grinding nearly if not quite as well as the stone, and it is hard to distinguish the cement from the stone. Plaster should never be used to cement the blocks together. White lead and glycerine, for filling holes in stone faces, cause poisoning.

La-Ferte-sous-Jouarre.—La-Ferté-sous-Jouarre, the centre of the millstone industry, is in the middle of the valley formed by the Marne, and running east and west. On both sides of this river are hills from 60 to 70 meters above the water level. The geological characteristics of La-Ferté

show all throughout the upper class of tertiary rocks. 1. The bottom of the valley is coarse limestone with argillaceous and limestone masses surmounted by grit rock and retiring on green sand. 2. The second part incloses, in certain places, separated beds of gypsum covered with marls. They rest on a siliceous limestone. 3. Beds of siliceous and micaceous sand under siliceous grit and over argillaceous marls. 4. Small beds of marine formations, well characterized, on the southern hill, by numerous fossils. 5. Siliceous burrstone, compact and porous, enveloped in clayey bands and siliceous and micaceous sands. The value of the burrstone is very variable in different quarries.

On the northern hill, at La Justice, there are quarries presenting all the elements of a complete study. At this point the burrstone deposits have a stratified form, below beds of clay having a thickness of from three to five metres. The millstone beds also vary in thickness, but generally between three and five metres. The deposits worked for burrstone rest on a clayey bed containing nodules of millstone, used for building purposes. The stratum of five metres of millstone is far from being homogeneous, and entirely good for making burrs. The upper bed is a white millstone, used for building. That immediately below contains the best stones, used for runners.

At the south the millstone rocks do not present, as at the north, any stratification; they are conglomerates more or less voluminous, dispersed here and there among clays and siliceous and micaceous sands varying from reddish brown to yellow and white.

The stone fit for mills is variously colored, from white to quite deep brown, including clear gray, bluish gray, sky blue, rose violet, barley-sugar yellow, grayish yellow and brownish yellow. These colors are produced by mineral oxides, and have no connection with the quality of the stones. To get at the stones the earth is removed above them by inclined railways. When uncovered, if the upper part is not good enough for burrs, it is blasted away until good stone is found, and this is carefully removed, according to the lines of stratification, and not broken up. When there are no such cracks, longitudinal grooves are made, and the stone is wedged out in blocks following the natural fissures. In some quarries water is abundant, and is removed by steam pumps, or by siphons when the lay of the land permits the latter.

After coming from the quarry the stones are sorted according to their respective qualities, and then by "lots." A "lot" contains enough material to make a millstone of medium diameter, of even color, grain and hardness, and of perfect homogeneity. I need not dwell long upon the absolute necessity of having the two stones which compose the pair or run of burrs made up of blocks evenly matched as regards hardness, porosity, etc., so that each stone may be as nearly as possible like one solid block.

In some establishments the stones are cut and dressed by hand. In that of Roger, Fils & Co. machinery is employed. The manufacture comprises several distinct operations. 1. Blocking out the sections, cutting them and perfecting the joints. 2. Assembling and cementing the blocks. 3. Hooping. 4. Truing up. One machine trues the face of each piece

which enters into the structure of a burr, and trues also the joint faces. A reciprocating table bears one or more pieces of stone which are faced up by a rapidly revolving tool bearing diamonds set "staggering." The tool has an automatic cross feed, so that each diamond levels the ridge left by the preceding one. The centre of the millstone being finished, its face is planed and its sides are cut to a right angle with this plane. A special machine is employed in assembling. This machine has a circular cast-iron bed-plate fixed and centered accurately on the eye of the burr, and also a movable straight-edge or arm also of cast iron and turning around a spindle passing through the centre of the bed-plate. This arm has a sliding scale permitting of determining exactly the diameter and the circumference of the burr. It has a strong rib, giving great rigidity and permitting of making stones perfectly plane and round no matter what the unevenness produced by the composition which fills the joints, each piece coming successively to bear upon

FIG. 173.—BURR-STONE QUARRY.

the arm, which resists all efforts tending to twist the surface of the burr. Instead of plaster as a bond for the blocks composing the burr, there is now employed by some makers a peculiar and very hard and durable lime cement. The iron hoop is then heated and shrunk on the rim about five centimetres (two inches) from the working faces, binding the sections very strongly together.

As the runner is to turn upon a vertical spindle, it must be of uniform weight in all parts. The back must be carefully filled up to a uniform surface. The stone rests on an iron tripod, on which is fixed an arbor passing through the centre of the eye. An iron bar carrying a horizontal cutting edge and another cutting vertically slides against the bearing, which embraces the central arbor so as to answer for any diameter of stone. The bearing touches a distance collar, sliding in the spindle and fastened by a set screw, thus regulating the thickness of the burr. Revolving the apparatus the run-

ning face of the stone is rendered truly plane. Iron polishing blocks, with suitable handles, give it a marble-like surface.

Plaster being essentially hygroscopic, and hence affected by atmospheric influences, stones should not be jointed with that material. During the opera-

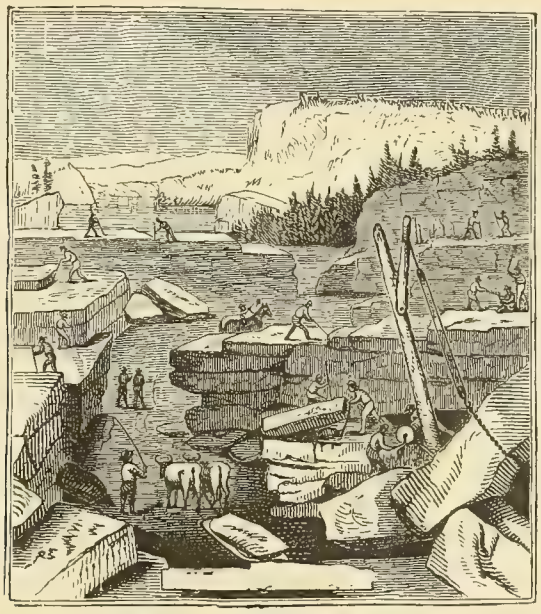

FIG. 174.—BURR-STONE QUARRY.

tion of truing there are placed on the running side of the stone cast-iron balance boxes containing adjustable weights.

The next and most important operation is dressing. This is the uniform and regular surfacing of the working surface of the burrs, and has generally been done by hand, in all countries, with a very sharp-edged hammer—the "bill" or "pick." The workman was compelled to breathe the siliceous powder produced by the blows of this pick. This occasioned serious maladies, rendering the substitution of machine work of double advantage. The

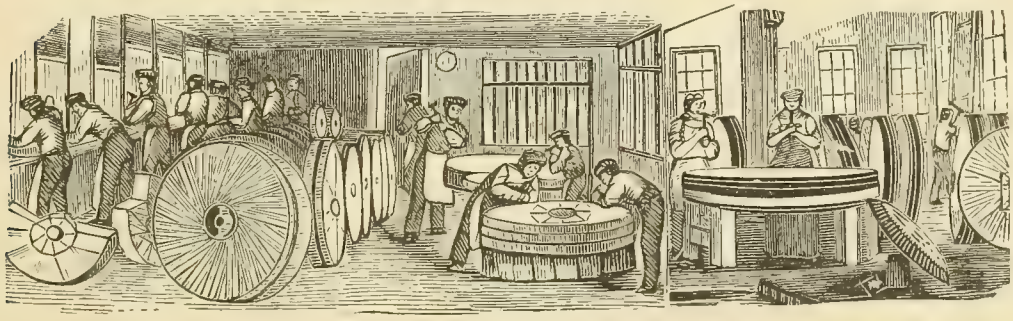

FIG. 175.—MILLSTONE MAKING.

French Society of Encouragement of National Industry offered a prize of 4,000 francs for the solution of this problem, and awarded it to Mr. Roger, Jr. His machine consists of a large face-lathe, having a tool-holder moving radially and carrying a spindle around with from eight to sixteen diamonds

placed staggering. The lathe in rotating presents each part of its face successively to the action of the diamonds, so that each cutting forces another out of the ridge left by the last. It is necessary to give the runner a certain amount of bosom, commencing at the eye and running to nothing at about fifteen to twenty centimetres from the circumference. The action of the diamonds avoids the bruises caused by the shock of the pick, and at the same time produces a more regular and durable dress. The result is less waste of stone and of time, less heating, greater yield and white flour.

Fig. 173 represents the interior of a millstone quarry, and Fig. 174 the excavation opening into the quarry. Fig. 175 represents the interior of the millstone factory.

Ordering Millstones.—State size, which way they are to run, whether with or without furrows, and, if furrowed, the speed they are to run, the quality of grain to be floured, preference (if any) as regards openness, preferred thickness of the bed and of the runner, what kind of irons preferred. If no irons wanted, give size of eye desired.

CHAPTER XXIII.

MOUNTING THE BURRS.

The Millstone — Building Up the Burrs — Size and Weight of Stones — Hurst Frames — Hoppers and Hopper Frames — Pinion Jack — Size of Pulleys — The Spindle — Different Forms of Cock-heads — Setting the Bed — Tramming and Bridging — Iron Jackstick with Level — To Make a Tram — Bush — Tram-Pot — Stiff *vs.* Oscillating Drive — The Balanced Bail — Ordering a Bail — Drivers — The Dane Driver — Equilibrium — Balancing the Runner — Standing Balance — Running Balance — Centrifugal Force — Radius of Gyration — Putting in Running Balance — Point of Suspension — The Damsel Feeders — Automatic Stone Lift — Iron Burr Crane — Oiling Mill Spindles — Fitting a New Back — Cost of Building Up.

The Millstone.—Nine out of ten of the burr-stones that have been working during the last twenty years have been badly hung, ignorantly dressed and wrongly run ; nevertheless, they have done nearly all of the flouring of the world. If, then, a device so improperly cared for and handled is capable of doing so much and so good work as the stone has done, much better can be done in the future when people understand it and develop its capacity.

In general it may be said, that if the stocks be well chosen, and the stones built up, dressed, set, hung and driven properly, excellent flour may be done by a competent miller. If, however, the proper precautions and skill are not used at first and continued, burrs need not be expected to turn out good work. In this matter, rolls have an advantage over burrs ; they require less knowledge and watchful care on the part of the miller, who becomes more of a mere manufacturer.

Building Up the Burrs.—The method of accomplishing this is given in detail in a former chapter. We merely add a few paragraphs, suggested as this chapter goes to press.

In regard to the question whether eye-blocks should be more or less porous or more or less close than those at the skirt, the head miller of one of the largest mills at St. Louis says that, for wheat-grinding, it is better that the eye-block should be more solid and a little harder than those at the skirt, because the amount of surface is small in comparison with the whole, and the wheat passing over that surface in a whole or slightly broken condition, has great scouring or washing power, enough at least to keep such blocks on an equal plane or level with the skirt-blocks. Now, if the position of the blocks is reversed, the wheat acts upon the soft and most porous blocks when in the condition capable of doing the most scouring or washing. The consequence is that cuts or rings are formed of such numbers and depth as to make good granulation impossible.

Stones have got into such a condition from the eye-blocks being soft and porous as to render them unfit to use on wheat, but having been faced down until the rings or cuts were taken out, and then put to grinding middlings,

have done very good work, because the middlings, acting upon the porous eye-blocks, allowed them to remain on an equal plane or level with the skirt of the blocks. The middlings not having that scouring or washing power of wheat, no rings were formed.

Size and Weight of Stones.—The five and six feet stones weigh from three to four thousand pounds each, bearing very heavily on the spindle step. Four-foot stones, weighing eighteen hundred to two thousand pounds, making 175 revolutions per minute, are about right for light water-power.

Hurst Frames.—These are preferably of iron, as being more solid than wood; but it is best to have a wood top which obviates the expansion and contraction due to changes in temperature to which the iron hurst frame is liable. To obviate this, especially where there is a line of burrs on iron frames, they should have wooden tops.

It is perhaps best that the lower part of the hursts be in the basement on an independent foundation. Three runs of stone are very commonly combined in one hurst, as one under-runner for corn and two upper runners for wheat.

Hoppers and Hopper Frames.—These are best made of extra quality pine or maple. It is desirable to have the shoe attached to the upper frame, which does away with the stand and permits the shoe to be removed with the frame, thus preventing the shoe from dropping down into the eye of the stone when loosened from the rolls.

Pinion Jack.—To lift a stone pinion out of gear a pinion jack is often employed; but a simpler way is with a shaft worked by handles with rigid stock and having short chains with hooks which are caught under the arms of the pinion and raised out by the turning of the shaft.

Size of Pulleys.—It may be necessary, in order to get just a certain number of revolutions out of one runner, to put in a special size that might really be too small or too large a pulley (generally the former) on the spindle. But where the transmission is such as to give a choice, the following table is based on usual practice:

Stone, feet diameter, ...	2	3	3½	4	4½
Belt, inches diameter, ...	4	8	10	12	14
Pulley, inches diameter, ...	16	24	28	30	32

Curbs.—The curbs should be strong, neat and tight, and, properly, should be built with a view to the addition of a millstone exhaust, the question of which is treated at length in another portion of this work. Under the head of "Millwrighting" will be found the detailed instructions for laying out and making curbs.

The Spindle.—The spindle should be tested in the lathe before it leaves the shop. See that the hole in the balance rynd or the cup in which the cockhead works is made exactly in the centre. The driver should be an exact fit of the section of the neck of the spindle, allowing one-fourth inch from its lower face to the spindle neck for sinking in wear. As steam-power is often unsteady, steam mills require stronger spindles than those mills using water-power. The spindle should be from eight to eleven feet in length, the latter length being recommended as most convenient for gearing.

The neck should be from ten to twelve inches long ; from the top of the neck to the point of the cockhead nine inches. In testing the spindle the point of the neck and step must correspond with each other.

The spindle should be of wrought iron, the cockhead and toe of steel. It is claimed by some that the bridge-tree should be somewhat elastic. Where rigidity is desired the spindle step should rest on the main bed-plate, instead of the bridge-tree being attached to the columns at a point above the bed-plate ; this precludes the possibility of trembling. Spindles should have raised collars. It would be well to have an adjustable spindle which could

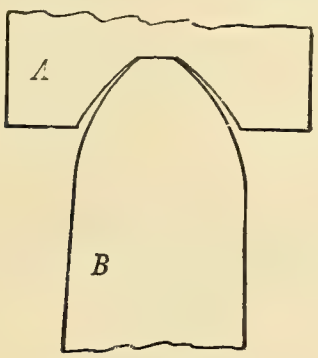

FIG. 176.—Wrong.

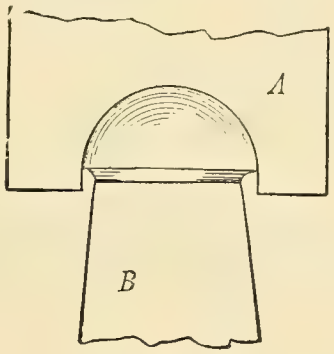

FIG. 177.—Right.

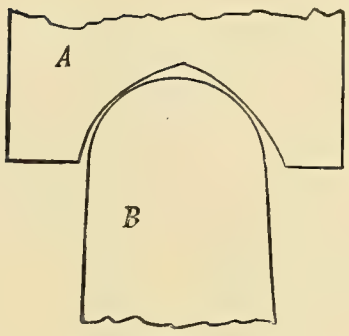

FIG. 178.—Wrong.

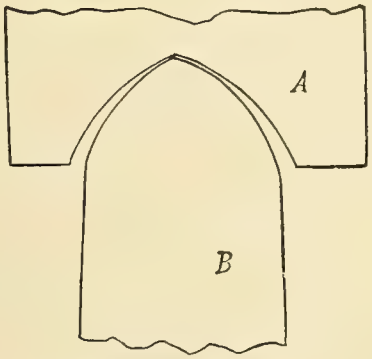

FIG. 179.—Wrong.

FORMS OF COCKHEAD.

be shortened in the eye so that the bail need not be detached when the face of the stone wears down.

Different forms of cockheads are shown in Figs. 176 to 179 inclusive. The second one, Fig. 177, is of the proper form to give free oscillation in every direction, as well as easy rotation. The others are bad forms in every way.

Followers should in any and all positions of the spindle have a full and uniform pressure throughout their entire length and breadth and against the spindle neck.

The ordinary form of wrought-iron spindle is shown in Fig. 180, the steel cockhead and toe being shown by the dotted lines to project into the spindle.

The mill spindle should be kept well oiled, because not only does the increased friction necessitate a greater amount of power to drive the stones, but the spindle itself becomes abraded, and may heat so as to stick in the step. The plan of putting a string around the spindle has the disadvantage that there is danger of having to take up the mill to put in a supply of tallow or oil. A better way is to guide oil through a small pipe, from the outside of the curb down below the husk frame and bottom stone, thence with an elbow toward the bush, just below the bush, thence through a hole or opening in the bush upward to nearly a level with the top of the bush, where a groove is cut just deep enough to admit the discharge end of the little pipe to sink below or even with the level of the top of the bush, and not be in the way of anything which might be used as a bush cover to keep out dirt and trash. By this means the spindle need not be looked after for a long time. Spindle bearings should be oiled each day. Tallow is the best lubricant for the collar; suet answers well. Many millers prefer wood for the box

FIG. 180.

around the collar of the spindle. Some prefer to fasten weights by means of hooks to the wedges which tighten the braces. With these the pressure is radially adjusted if the spindle heats or if it becomes loose.

Setting the Bed.—Lay the stone down in its proper place, with the back even and solid on the timbers. Level the face correctly with wooden wedges between the stone and the timbers, and then, without deranging the level, drive wedges all around the verge, to keep it from moving sidewise. Clean the plaster out of the eye, wet the remaining plaster, dropping in the bush with the upper part half an inch above the face of the stone. See that the bush is exactly centred, wedge it in place, plaster up all crevices below with clay, then run in thin plaster on the bush next the stone.

When the plaster is hard, put a board in the centre of the bush, find its centre, and make a small hole through it and pass a plumb-line. With the plumb-line as a guide, move the step on the bridge-tree, so that the hole in it agrees with the centre of the bush, then fasten the step. Now put the spindle in place and tighten the neck.

Whenever the runner is taken out, the bed-stone should be tested and leveled if wrong. A better plan then wedging is to have cast-iron plates inserted in the backs of the bed-stones, to receive the pressure of leveling screws inserted in the under side of the hurst.

Tramming and Bridging.—Take a piece of wood twenty-four to thirty inches long, tapering from four inches to one, cut a square mortise through the wide end to fit the square cockhead. In the smaller end make a small hole about two inches from the verge of the stone; fasten in this a quill set to touch lightly and to play around the face. Fasten the tram on the square neck and move the spindle gently around, noting what parts of the stone the quill touches. Alter the wedges or screws until the quill

touches the face equally all around. If stones are out of tram, the pressure will be harder on one side than on the other, causing the driving points to wear more on one side than on the other, while at the same time one side of the stone grinds closer than the other.

The stones should be trammed every time they are dressed. When not in tram they will rub in parts and make dark and specked flour. An improvement over the ordinary wooden board tram is the iron jackstick with a level, and all parts adjustable.

The Iron Jackstick with Level is shown in Fig. 181. It is fixed firmly on the spindle with the screws A B C D just below the cockhead. The level is adjusted by a set-screw, F. When the bubble E in the level retains the same position in the tube, no matter in which way the jackstick is turned, the spindle must be perfectly vertical. A quill, G, being fixed on

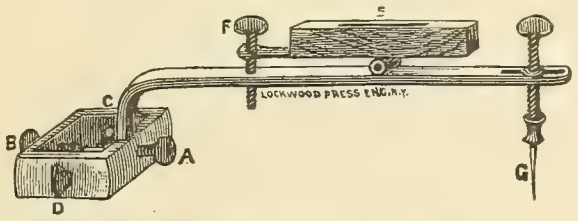

FIG. 181.—IRON JACKSTICK WITH LEVEL.

the outer edge of the jackstick and brought down just to touch the floor of the stone, will enable one to see whether or not the bed-stone is perfectly horizontal.

During this operation the bubble should be watched to see that it does not leave the centre of the level, which would prove that the jackstick had got loose on the spindle, and consequently the indications of the quill would not be correct.

Bush.—A good bush not only keeps the spindle in place laterally, but by keeping it cool prevents it from rising and falling, and thus makes the grinding uniform and better. The advantages of a perfect bush are that the followers will adjust themselves to the spindle under all conditions, whether in perfect tram or "out" in any direction. When a spindle is out of tram it is so in one of three ways: Either it is slightly displaced laterally while remaining in true vertical position, or it is reasonably central but out of plumb or verticality; or both. The first case very seldom happens, the second is the most frequent. Now, it is evident that in such a case the sides of the spindle are inclined, and that the followers, in order to fit them exactly, must also be inclined in the same degree and direction. The ordinary bush has an arrangement for follower adjustment laterally, so that they may all be just as far from the true centre line of the step as the top of the spindle is. The more inclined the spindle is, the more inclined the sides of the followers must be. We must then have followers that will accommodate themselves to any degree of inclination of the spindle, as well as to any degree of eccentricity of the cockhead. Now, when we come to think of it, the spindle may be out of plumb, with regard to the central line which it ought to assume, in two directions—say, in a north and south direction, and in an east and

west direction. The follower must, therefore, have adjustability in all directions in the horizontal plane. In order to fit the sides of the spindle, the centres of adjustability of each follower must be in its centres of height and of length.

The Kuehne & Bryant bush,* Figs. 182 and 183, has followers with ad-

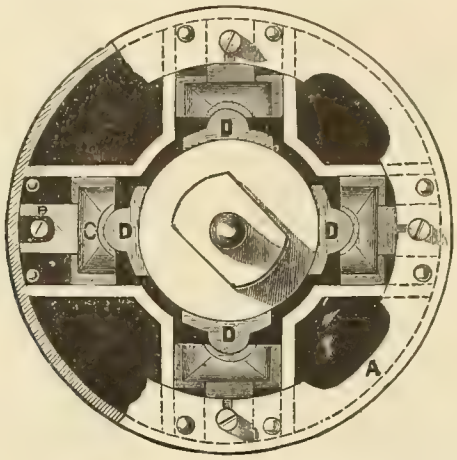

FIG. 182.—KUEHNE & BRYANT BUSH.

justability in both directions horizontally, and each follower has locking wedges operated by screws, the gibs having double-inclined backs with inclined faces connected to the gibs by vertical bearings and seats, and extending the entire length of the followers or gibs. The followers are of cop-

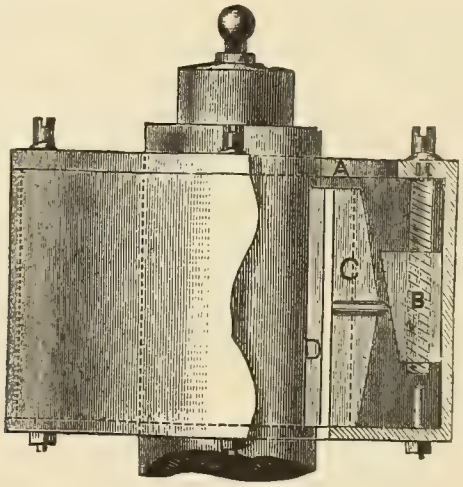

FIG. 183.—KUEHNE & BRYANT BUSH.

per, brass or babbitt, as desired. It will be seen that the followers have automatic adjustability for inclination of the spindle and for its lack of centrality. In addition to this, wear of the followers may be taken up by the wedge B and screw. In the cuts, C represents the iron backing of the follower and D its brass, babbitt or copper face.

Fig. 184 shows the ordinary bush, which is provided with a collar placed above it.

* Kuehne & Bryant, Chicago, Ill.

Tram-Pot.—Tram-pots are either centre-lift or top-lift, the latter being the most used. The centre-lift requires the bridge-tree to be pierced for the lift-rod to pass through. The top-lift is much more convenient. The tram-pot is often set on an arch over the line shaft. Fig. 185 shows an arch tram-pot to bridge over the horizontal shaft of bevel-geared mills, Fig. 186 being a centre-lift pot. Figs. 187 and 188 show forms of top-lift tram-pots.

Laying off and Cutting the Holes for the Balance Rynd.—Lay the runner perfectly level, face upward. Fit a planed board in the

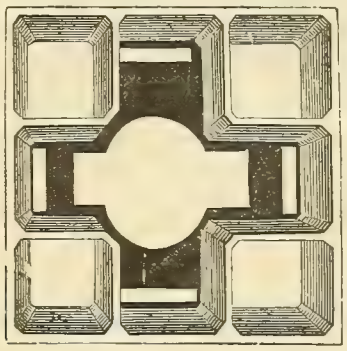

FIG. 184.—ORDINARY BUSH.

eye, divide it into quarters and find the centre, making the mortises nearly an inch longer and wider than the thickness of the rynd.

The mortises for the driver must be laid off on the opposite quarter-marks; there should be cast-iron boxes for the driver to work in, one-fourth of an inch wider than the journal.

To make the mortises good chisels and heavy picks are needed. The sides of the mortises must be straight and square from the face of the

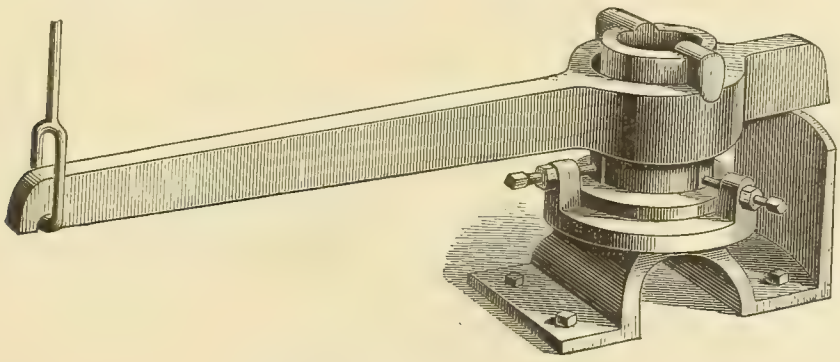

FIG. 185.—TOP-LIFT ARCH TRAM-POT.

stone. When the box mortises are nearly the proper depth, drop the boxes into place to test them. Drop the driver on the spindle, fastening it so as not to drop off. The balance rynd being in its proper mortises and at the right depth, put the spindle point into the centre of the rynd and the sides of the driver into the boxes. If the driver rides on the bottom of the boxes, take them out and deepen the mortises, as the spindle point should have free play in the holes of the rynd, leaving plenty of room between the bottom of the boxes and the driver.

Fastening the Rynd and the Driver Boxes.—See that the rynd is true and the whole well centred ; take a smooth strip of wood the

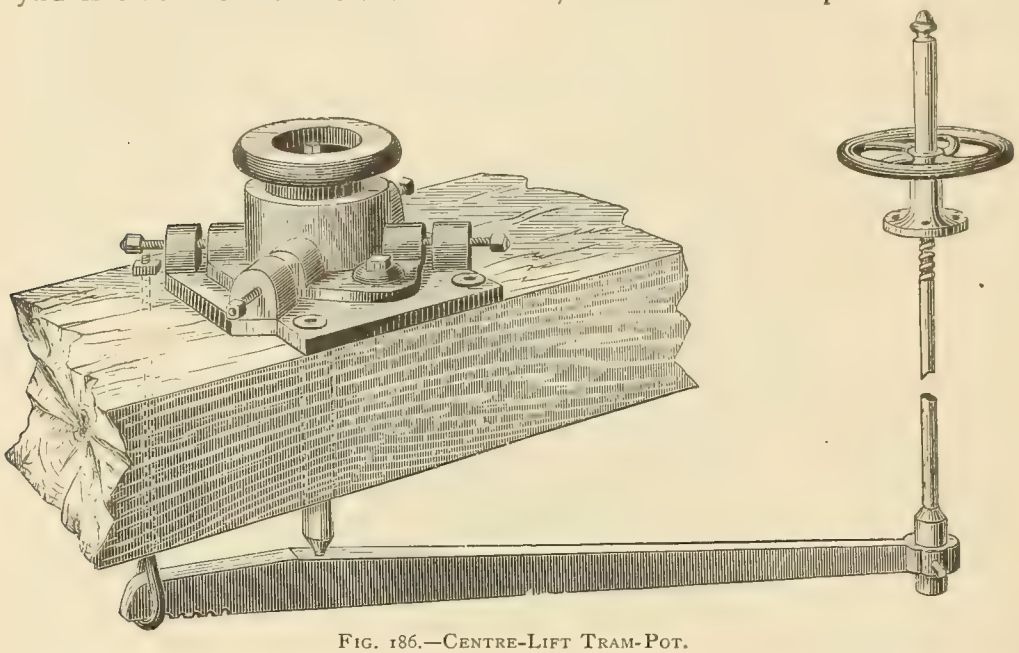

Fig. 186.—Centre-Lift Tram-Pot.

width of the lugs of the rynd and the thickness of the iron ; fit this closely across the space between the lugs and even with that face which would be

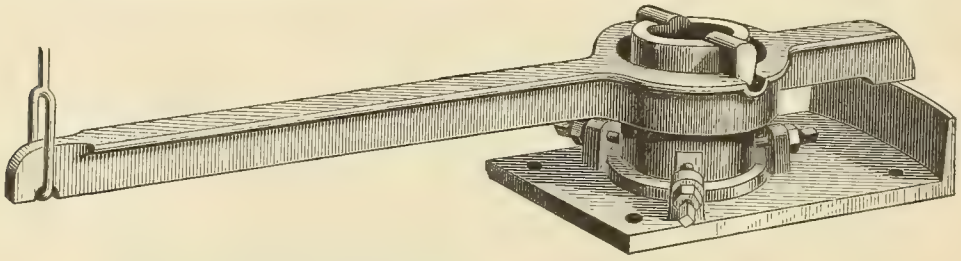

Fig. 187.—Top-Lift Tram-Pot.

next the stone ; lay the small straight-edge on the lugs, and over the strip apply the iron square to the straight-edge. Put one edge on the centre point

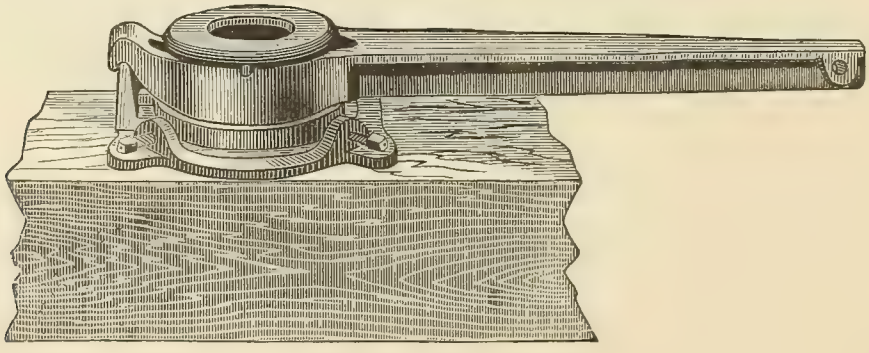

Fig. 188.—Top-Lift Tram-Pot.

in the rynd and mark the strip ; reverse the square and mark ; if both points agree, that is the centre ; if not, divide it evenly.

Place the balance rynd in the stone with the centre of the thickness of

the lugs even with the quarter-marks. Lay a straight-edge on the stone, and from the opposite quarter-marks make a line across the mark on the strip. This will be the centre of the stone. Lay the straight-edge on the other quarter-marks, and move the rynd until the centre or line on the strip is even with the straight-edge. If it then agrees with the other quarter-marks, the rynd will be properly centred. If the line is not perpendicular, the spindle will wear the hole to one side.

Drive small iron wedges around the edges and sides of the rynd. Stop the sides of the mortises with stiff clay and run in lead until it reaches above the surface of the mortises, then settle it down closely with the cold chisel and hammer.

To set the driver boxes put the driver on the spindle, place the boxes on the driver with a piece of wood a quarter of an inch thick, and a piece on the ends to prevent the driver touching either the ends or the bottom of the boxes, then drive wedges between the sides of the driver and the boxes, and fasten the driver in them. If the bail is not fixed perfectly central in the

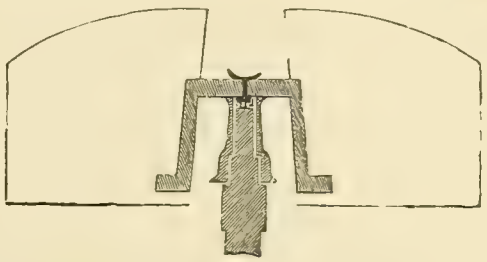

FIG. 189.

stone, one side of the stone will be heavier than the other, and while standing the heavy side will hang the lowest. The inside of the bail should be of the same diameter as the eye of the stone. (See Fig. 189.)

The eye of a 4½-foot stone may be 10½ inches at the base, tapering to 7 or 8 inches at the back, the runner stone being 20 inches thick at the eye and 15 at the skirt.

Stiff vs. Oscillating Drive.—As regards the question of stiff or oscillating connection, it is very easy for any miller who has two runs of burrs to try the two side by side and judge which one is best adapted to his work. It may, however, be said in general terms that the stiff drive requires better workmanship and care than the balanced, but that modern methods permit much greater stiffness of the building and of the hurst, and greater accuracy of face, than was common fifty years ago ; hence stiff drive is now more possible than formerly, and gives more and more satisfaction each year, especially for ending, hulling and pearling, and for middlings flouring with burr-stones ; and the high-speed iron disc stiff-driven under-runner break machines of the Jonathan Mills' system owe their success very largely to the advanced ideas of mechanical instruction embodied therein, such as extra long bearings, ample wearing surfaces, and great rigidity of the iron frame. The balanced drive gives the miller a better chance to let the condition of his burrs deteriorate than the stiff drive does. With stiff spindles there is some-

times trouble keeping the driver in the runner. Where the husk frame is old and rotten, there will be apt to be trouble with a rigid driver.

The Balanced Bail.—The advantages claimed for the balanced bail over the fixed are: 1. The runner, while so supported that it shall revolve evenly upon the spindle, with its face perfectly horizontal, always retains this position while in revolution, even though the spindle does not stand truly vertical, so that if the face of the bed-stone lie perfectly horizontal, an equable distance may be maintained between the two stones. 2. That on raising the stones the bail may be freed without trouble from the spindle, while the driver remains attached to it. Moreover, it is not necessary, as with a fixed bail, to free it by force from the millstone, which is liable to cause derangement of the bail. The runner, while freely moving, easily yields to large or small foreign bodies which may chance to get between the grinding surfaces, without displacing the bail, which sometimes happens with fixed bails.

There are, however, cases where the balanced bail cannot at all compete with the fixed, among which we may reckon: 1. Where the runner is very large and at the same time of very unequally distributed weight, making the restoration of the running balance very difficult. 2. When it is necessary that the distance between the stones should be strictly maintained, as in the case of pearling stones. 3. Where the distance between the two grinding surfaces must be very great, so that the runner has plenty of play for oscillation, which would spoil the grist, or the grinding surfaces would be apt to be spoiled by the considerable sagging and impact of the stones.

In ordering a bail, the maker should guarantee and the buyer should see that the following conditions are observed: 1. The point of suspension of the bail must be so constructed that while strictly horizontal the stone may be easily depressed in any direction without showing any greater resistance in one direction than in another, otherwise the balance bail will have the disadvantages of the fixed bail. The driver must be so constructed as not to interfere with this easy motion in any direction. 2. The point of suspension of the bail upon the spindle must lie in the centre or axis of the spindle and the stone, and both axes must fall into one and the same vertical. 3. The point of suspension of the bail upon the spindle must lie in a vertical line over the centre of gravity of the stone. When the centre of gravity lies beyond the axis of revolution, the runner is only in standing balance, and on the slightest resistance causing the oscillation of the runner, the latter must sag down in one direction and remain in this position. When, however, the centre of gravity of the stone and axis of revolution coincide, the runner will be in equilibrium, whatever its position; and if such a case were to occur that the centre of revolution lay beyond the centre of gravity, the runner, if thrown out of the horizontal grinding plane would, by its vibrations, show its effort to regain its original position. 4. The driving-point of the driver must, if possible, fall into the same horizontal plane as that in which the point of suspension of the bail lies, so that the pressure exerted in the transmission of the motion shall not necessitate the employment of an arm, which would have a tendency to throw the runner out of the horizontal position. In any case, the driving-point of the driver should not lie lower than the centre

plane of gravity of the stone, because the motion would then become rocking and unsteady. 5. The points of attachment of the bail in the stone must, if possible, fall into the same horizontal plane in which lie the working points of the driver. This is especially desirable where the driver grasps the bail, as in most arrangements, for if these conditions are not sufficiently fulfilled, the pressure of the driver on the bail will tend to loosen the latter in the stone.

Drivers.—There are several kinds of drivers for millstones. Many prefer the oscillating form, as it has some advantages when the spindle gets out of tram, which should never be allowed to occur. Rigid drivers have their advocates, and it is claimed for them that they keep the burrs in better face, not allowing them to get in wind, and make a more even granulation. They would work better, however, with gearing than with belts, as the belt presses the spindle too much to one side, and this pressure has a tendency to throw the spindle out of tram.

The Dane Driver.—In one of the best drivers (Figs. 190, 191, 192), patented byJoseph C. Dane, Lacrosse, Wis., the spindle is made in the usual form, and is provided with a carrier pin passed through it near its upper end. Upon this the driver rests. The driver has a notch across the under edge of each side to fit over this pin. By this means the driver is carried around with the spindle as the latter revolves. The driver has jaws on opposite sides, lapping upon each arm of the bail, the bail being of the proper form to fit the eye of the burr-stone. The bail has a balance pin or cockhead passed down into an opening in the upper end of the spindle to the centre of the carrier pin. The end of the pin is pointed, and rests in a recess in the carrier pin, thus making the point of suspension and drive in the same plane. The jaws of the driver are beveled off above and below the line of drive to allow the bail to work in the jaws without friction. To keep the driver level as it rests upon the carrier pin there are two pins inserted in the under side of the bail, projecting down to and nearly touching the driver, thus holding it to a level position. This gives an easy motion upon all points of the compass and a facile adjustment to the runner, so that it will present an even face to the bed-stone at all times, even when the spindle gets out of tram.

By placing the point of suspension and the line of drive on the same plane, and that plane placed in the centre of weight of the stone, and having the stone well balanced, the stone will run steadier and present a more uniform face to the body of the stone, and by its ease of oscillation it will relieve itself of any foreign matter, such as a nail or piece of wire, quicker and easier than any driver will that has the point of suspension above the line of drive, for in any of these there is more or less slip of the driver. Such a driver will admit of the stones running closer together without rubbing, thereby grinding the flour more evenly and finer, and producing a better grade of flour. It ought to make more and better middlings from wheat on the first grinding and leave larger bran. With such a driver there should be no wabbling, rubbing, or pounding when starting or stopping the stone, thereby preventing wearing or scuffing of the skirts, saving much time and labor in dressing, and will run longer without dressing than with drivers that

are not made on this principle of having the line of drive and the point of suspension in the same plane being placed nearly in the centre of the weight of the stone.

One Dane driver of which we learn is stated to have been in constant use for nearly four years, wearing only sufficiently to show the bearing places. It

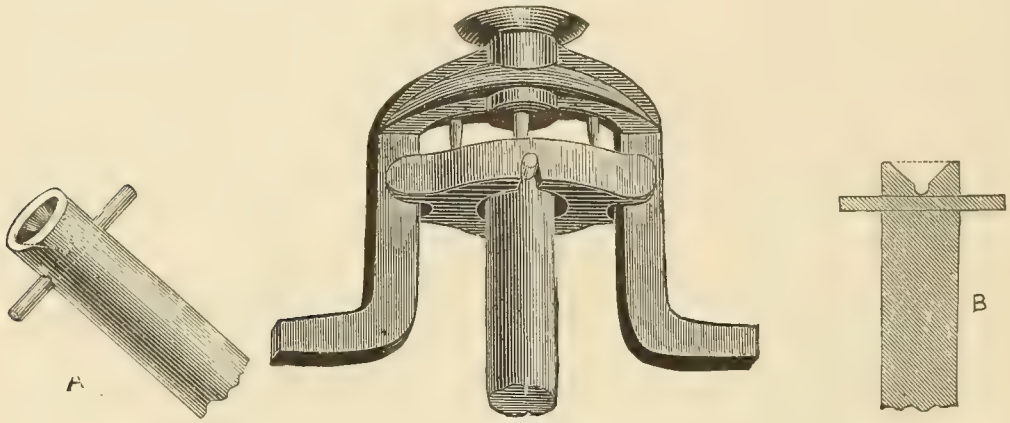

FIG. 190.—THE DANE BAIL AND DRIVER.

can be fitted to any old spindle now in use by fitting the bail and driver to a sleeve that will slip on the top and fit the old spindle.

Equilibrium.—Even balance is of three kinds: stable, unstable or indifferent. A balanced body is in indifferent equilibrium when it will remain

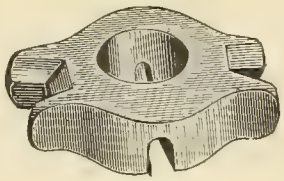

FIG. 191.—DANE DRIVER.

in any position in which it is placed, although it is free to turn. A well-balanced loose pulley or vertical burr on a horizontal shaft is in indifferent equilibrium.

A balanced body is unstable equilibrium when it has a strong tendency to

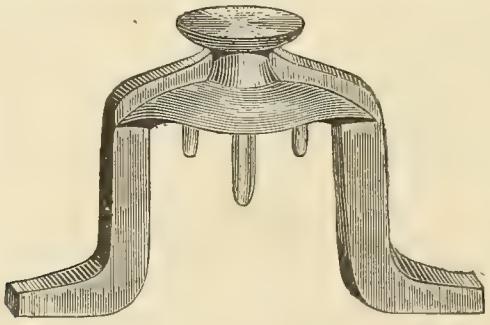

FIG. 192.—DANE BAIL.

assume some other position than the one in which it is balanced. Of this class, a lead pencil balanced on end or a whip on a man's nose.

A body is in stable equilibrium when there is some one position which it will assume in preference to any other, as a horizontal millstone.

Fig. 193 shows how stable equilibrium is given to scale beams, the knife edges which carry the pans being lower than the point of suspension of the whole beam. If they were on the same level the beam would be forever on the topple and it would never stand still.

Fig. 194 shows why it is that the heavy side of a stone rises when the

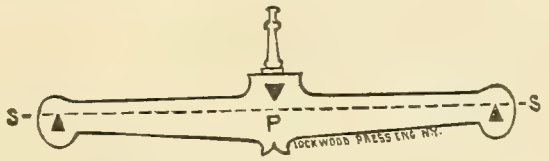

FIG. 193.—STABLE EQUILIBRIUM.

stone is in motion, although it is the lower side with the stone. The stone which hangs down when quiet tries to get as far away from the centre as possible when made to rotate around an axis. This is the principle of the steam-engine governor.

Fig. 195 shows the balls in unstable equilibrium, and Fig. 196 shows the

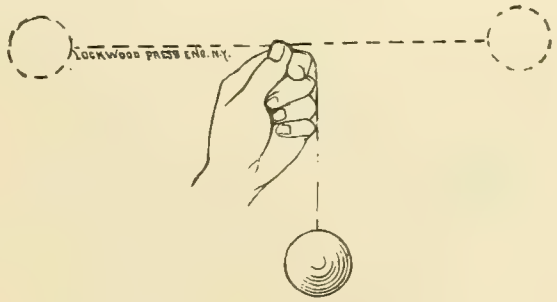

FIG. 194.

balls in stable equilibrium, with the point of suspension upon the centre line of gravity.

Balancing the Runner.—The runner should be balanced upon the

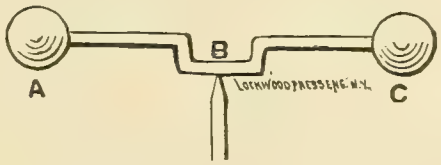

FIG. 195.—UNSTABLE EQUILIBRIUM.

pivot of the spindle. There are three kinds of balance—standing, running, and starting, although, perhaps, this last may be omitted.

A stone is in standing balance if, when hung upon the spindle, it stands

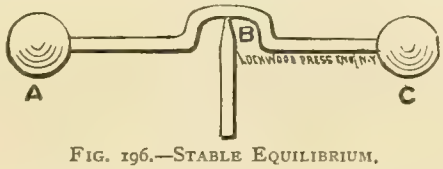

FIG. 196.—STABLE EQUILIBRIUM.

the same when turned in any direction. But a stone may be in perfect standing balance and in very bad running balance; and as the only usefulness of the balance stone is when it is running, it is more important to get the running balance than the standing.

As regards the height of the cockhead, the stone must be so suspended that a horizontal plane through the point of suspension will divide it into two parts of nearly equal weight, the under part being slightly heavier. If the upper part were the heavier the stone would be in unstable equilibrium. Although perfectly balanced if the upper and lower were exactly equal, yet it would be in indifferent equilibrium.

To put it in stable equilibrium, it is necessary that there shall be a slight preponderance of weight in the lower half.

Standing Balance seems often to be one of the greatest bugbears of the miller, and yet there is nothing about it to frighten any body or to cause him to lie awake at nights. Standing balance can be got and maintained very easily by having round the millstone a hoop of iron with a right-hand screw at one end, the other end being riveted to the burr after the proper length has been attained. The ends may then be joined. In order to tighten the hoop, the bolt joining the two ends may be turned very easily by means of a nail inserted in a hole drilled through the bolt.

Fig. 197 shows very crudely how to correct the weight of a stone that wabbles much, by screwing on a piece of iron, *g*, as shown at *e*, on the oppo-

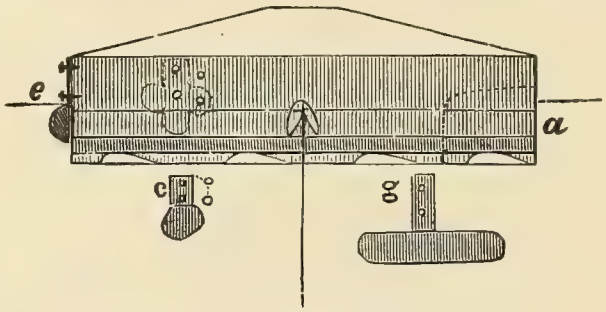

Fig. 197.—Attaching a Balance Weight.

site side from where the stone hangs down, within an inch or two of the face of the stone. If the spindle be in the centre of the stone, and the latter be out of balance, the trouble will most likely be a heavy block of burr on one side, as at *a*.

Running Balance.—A stone may be in prefect standing balance, yet very much out of running balance. This is because it will be in standing balance if there is as much downward pull of gravity on one side of any vertical diametral plane as on the other, no matter whether or not there is equal mass or weight. In the matter of standing balance, one pound two feet from a central vertical plane has as much influence in causing a downward pull of gravity as two pounds one foot.

The tilting influence of a weight in standing balance is measured by its mass (or weight) multiplied by its radial distance from the axis. When, however, it comes to running balance, the vertical action of terrestrial gravity, or mere weight, is largely superseded by that of the so-called centrifugal force, tending to throw the portions of a rotating body outward from the axis, no matter in what position that axis is, vertical, horizontal or inclined.

Centrifugal Force.—The force or influence tending to throw a revolving weight from its centre of revolution is measured by its weight, times

the *square* of its velocity, and divided by its distance from the centre of rotation. Expressed differently, it is equal to a force which would give the mass its stated velocity in *a space equal to the diameter of the circle*, because a revolving body reverses its direction in going around the circle of revolution.

Radius of Gyration.—In the case of the runner of an under-runner mill, which stone has no eye, but is a uniformly thick disc, the weight of the burr is supposed to be concentrated in a circle called the circle of gyration, the diameter of which is .707 times that of the diameter of the burr.

The centrifugal force of a revolving disc, of uniform thickness, is got by multiplying the weight by the square of the velocity at the gyration circle in feet per second, and dividing by the radius of gyration in feet and by 32.2 ; or by multiplying the weight by the square of the number of revolutions per minute and by the radius of gyration in feet, and dividing by 2935.

Thus, in a four-foot burr, the gyration circle has a diameter of $4 \times .707 = 2.828$ feet, and a circumference of $2.828 \times 3.1416 = 8.8844$ feet. If it makes 150 turns per minute, its rim speed is $150 \times 8.8844 = 1332.6667$ feet per minute, or 22.2111 feet per second. Supposing it to weigh 1,000 lbs., its centrifugal force will be, by the first rule,

$$\frac{1000 \times 22.2111 \times 22.2111}{1.1414 \times 32.2} = 10835.1481 \text{ lbs.}$$

By the second rule, its centrifugal force will be

$$\frac{1000 \times 150 \times 150 \times 1.414}{2935} = 10839.863 \text{ lbs.}$$

In the case of a flat rotating ring, such as a flat millstone of equal thickness, with an eye, the radius of gyration is rather more difficult to determine accurately, and we shall not consider it here. I have merely introduced the abstract subjects of centrifugal force and gyration to set the reader thinking, and to point out very markedly the difference in the forces acting in a standing and in a running millstone.

The centrifugal force of a homogeneous ring of rectangular section, rotating on its centre, is equal to half the weight of the ring, times the square of the number of revolutions per minute, times the square root of the sum of the squares of the outer and inner radii, the whole divided by 2933.5 (or more roughly, by 2935, as in the former case). Put as a formula :

$$F = \frac{W n^2 \sqrt{R^2 + r^2}}{2933.5}$$

The radius of gyration of such a body is equal to the square root of half the sum of the squares of the outer and inner radii, that is, to

$$\sqrt{\frac{R^2 + r^2}{2}}$$

Balancing.—A burr that is in running balance at one speed will seldom be so at another speed ; consequently, it ought to be given running balance at the speed at which it is to be worked.

It must be remembered that the tendency of a revolving weight is not to rise, and it is not to fall, but it is simply to get as far as possible from the axis. If the overweight is below the centre line, as in Fig. 179, or in the case of a millstone which has the point of suspension pretty well up above the cen-

tre plane of gravity, it will tend to rise. This is the case with millstones, because they are built below of solid burr, and in the upper portion of a lighter material; but balancing weights put into the upper portion of the burr tend to throw that portion down when running, whereas the same weights, if put in the lower portion, would tend to throw it up.

Fig. 198 shows a section of a burr through two blocks of unequal depth.

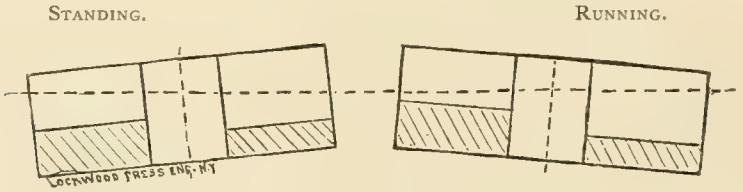

FIG. 198.—TENDENCY OF THE HEAVY SIDE.

While the burr stands the heavy block tends to keep that side down, but when running the heavy block tends to tip its side up. The wrong method of balance in this burr is shown in Fig. 199, in which the light weight, being on the heavy side, but pretty well toward the lower portion of the burr, tends to tip that side up. In Fig. 200 correct balancing is shown.

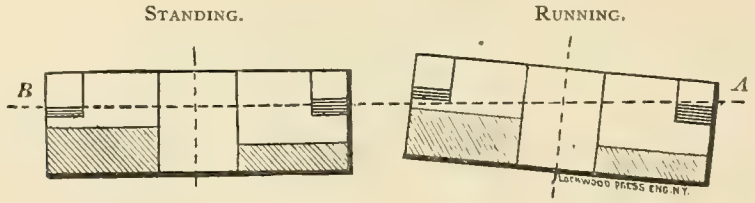

FIG. 199.—WRONG ARRANGEMENT.

Putting in Running Balance.—The following is one plan for putting in a running balance: Take two boards of hard wood, one-fourth of an inch thick, eight inches wide, and about five feet long. Raise the runner and put these boards between the stones at a proper distance from the eye and skirt, and nail the ends of the boards to the floor. Set the stones

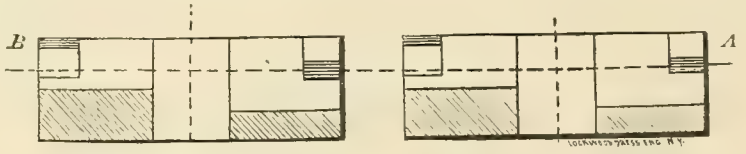

FIG. 200.—CORRECT BALANCING, EITHER STANDING OR RUNNING.

running with as much weight on the boards as will allow it to run easy, yet resting firmly on the boards. Make a rest over the stone and turn off the top perfectly true from the eye to six inches from the skirt, and then take out the boards. Now set the stone running at full speed, and, with a pencil at the rest, mark lightly where the stone is the highest. You can now use your judgment as to how much the stone runs out of balance or out of its plane surface, at a fair speed of 175 revolutions. After putting in lead in the light side, start up again and mark as before. The stone should be raised so as not to touch the bed-stone.

In balancing, if a heavy block was at the heavy side, as at *a*, Fig. 201, many millers would put the weight at B, to put it in standing balance; but this would be wrong, as it would make the running balance that much worse.

Fig. 202 illustrates what is called the "Common Sense" millstone balancing device. The principle of this device is to load the stone even, and thus have running and standing balance at any speed. The cut shows two shot cups in each quarter of the stone, one above the cockeye and one below the

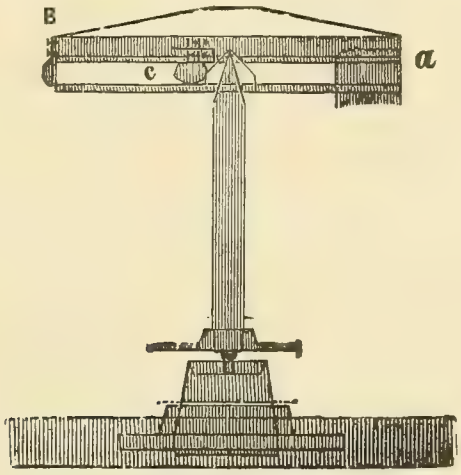

FIG. 201.

cockeye. These cups will hold about eight pounds of shot each, which is sufficient to overcome any surplus heft there may be on the opposite side. There is a screw with a big head through the band into the back side of the cup, which is removed to admit the shot, or to remove the shot should there be too many in the cup. These cups are accessible at any time. After finding the light place in the stone, remove the screw and put in shot until balanced. The cut represents half of the millstone, showing the location of four of the eight shot cups. If the stone is three pounds heavier at cup 2 than it

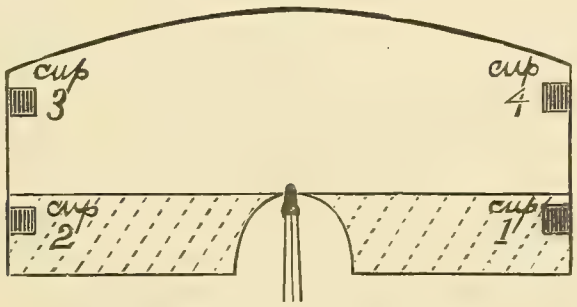

FIG. 202.—MILLSTONE BALANCING DEVICE.

is at cup 1, all other parts of the stone being of equal weight, the surplus weight is below the cockeye, and when standing still that side of the stone will drop down, being three pounds heavier than the opposite side; but if the stone is run at 150 revolutions, the heavy side will incline upward the same as engine governor balls. Now, by putting three pounds of shot in cup 1, there is just as much weight below the cockeye on one side as on the other. If there was a surplus of three pounds near cup 2, and of five pounds near

cup 3, the stone would be in a bad shape indeed, and with the usual means of balancing would cause a very tedious job; but with the cups located as shown in the diagram, it is said to be very simple and easily done. Put five pounds in cup 4 and three pounds in cup 1; now it is loaded evenly again, with the same result as before. Take still another case. Suppose there is three pounds surplus near cup 2 and three pounds near cup 4; in this case it would be in standing balance, but very much out of running balance, because, when running, the surplus weight at cups 2 and 4 would incline to come on a level with the cockeye, or point of suspension; but if three pounds of shot are put in cup 3 and three pounds in cup 1, it will be loaded even again, and of course is in standing and running balance. To get a good running balance the weight must be equal on all sides of the cockeye, both above and below it. If there is a surplus weight on one side below the line of suspension, the same amount must be put on the opposite side below that line.

Brown's method for obtaining running balance is to take two thin pieces of thin close-grained burr four inches long and six inches wide, plain gauge, and dress them down to about three-eighths of an inch thick throughout; raise the runner to half an inch clear of the bed, and slip these pieces between, one on each side, and about half-way from the spindle to the outer edge; slip a piece under each projecting end of these to fill the space between them and the face, and drive a nail down through to keep them all firm. Now, start the stone and let it down until it scrapes upon the board, and, while it is fitting and flushing the surface of these fit a plank over the top of the stone in a convenient place for a rest, and turn the whole back off perfectly true. If the face is kept down tight to the boards the back will agree exactly with it. Now, stopping the stone, raise it up and remove the boards. When started again at working speed and clear of the bed, it will take its regular running position, and its light side may be marked by holding a lead pencil against the raised plank and moving it carefully down until it touches the new-turned back. Stopping the stone, dig out a portion of the plaster next the hook on the marked side and run in some lead. Start and test again, and continue this until the pencil marks equally all around the back. As long as the motion is kept up the stone will run exactly true, and when the motion subsides one end of the stone will drag unless the stone is also on the true standing balance, which is unlikely.

To get the standing balance without disturbing the running raise the runner, and with a hand on each side move it each way until it is clear of the driver and free to balance every way around the pivot; now try it all around to find the light side, and weight that side until it balances alike. Mark the side across the hook, turn the stone on edge with that side up, and measure the distance from the face of the stone to the pivot-socket in the bail; then measure the same distance from the face on the edge of the stone, and mark that on the hook; the intersection of these two marks will show the centre spot where the lead should be put in theoretically. Practically, run the weight in two inches below this point, because the force is applied below the point of suspension about four inches.

Point of Suspension.—Fig. 203 shows four different kinds of points of suspension. The sharp point, No. 1, is the most sensitive, but would very soon get banged up, which would alter its level and the balance. Rounding it, as in No. 2, it is still subject to the same objection. If it is flat on top, the centre bar is apt to ride, so that the half-circular top, No. 3, or

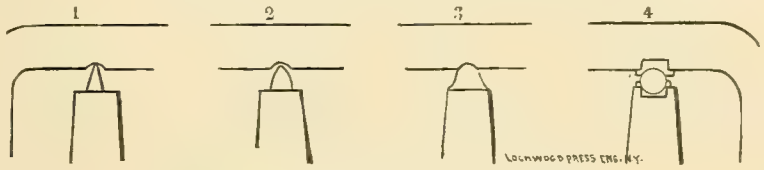

FIG. 203.—METHODS OF SUSPENSION.

the perfect globe, No. 4, offers the best kind of a point of suspension, being easy to make and keep in true, and not liable to be damaged.

One common fault with some universal driving irons is that the four trunnions are not exactly on the same level. If there are two points of suspension or centres of oscillation on two different levels, B and C, Fig. 204, it will be very difficult or even impossible to properly balance a stone so hung.

To W. E. Sergeant, of Minneapolis, we are indebted for some very practical directions for ascertaining the centre plane of gravity and deter-

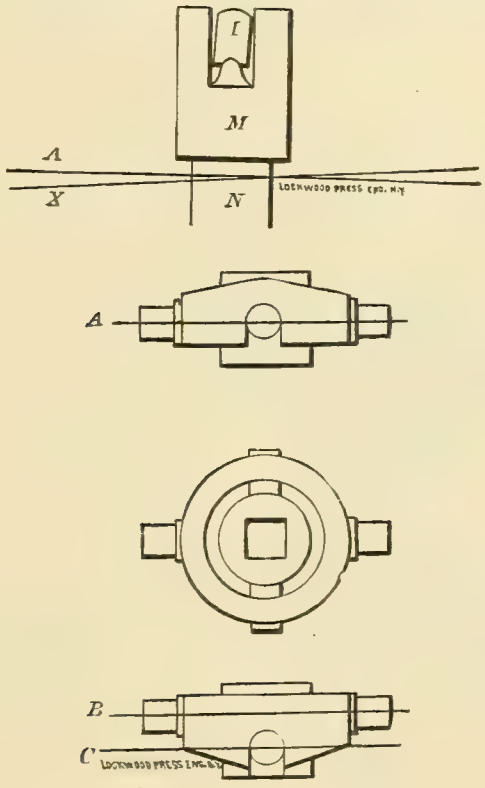

FIG. 204.—FORMS OF DRIVING IRONS.

mining the point of suspension of a millstone. If the volume of the blocks composing this burr were known and the weight of each, it would be a somewhat difficult mathematical calculation to determine where this central plane of gravity lay; but as it is we have no knowledge of the materials

which enter into the construction of this composite body, and some practical test must be applied, without special machinery, to find this central plane. Many complicated methods could be devised. We think that few

FIG. 205.—DAMSEL.

could be more simple and practical than the following: Plumb a post in the mill; be sure that it is not approximately but absolutely plumb. Roll the burr up against it so that its face shall lie up against and alongside of the

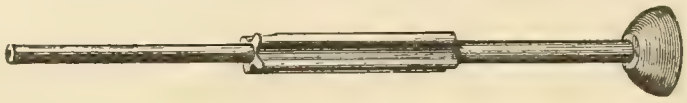

FIG. 206.—DAMSEL.

plumbed post. Take a large three-cornered file or a similar balancing edge in front of the plumbed face and parallel with it, at a little less distance from the post than half the thickness of the burr. Roll the burr upon this file and

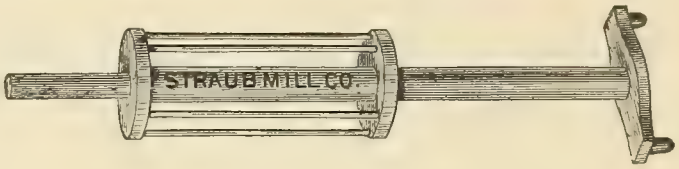

FIG. 207.—DAMSEL.

note where it leans toward and from the post. By rolling it off the file and trying new balancing points from time to time some new balancing points will be found. One point will be found at which the burr does not tend to

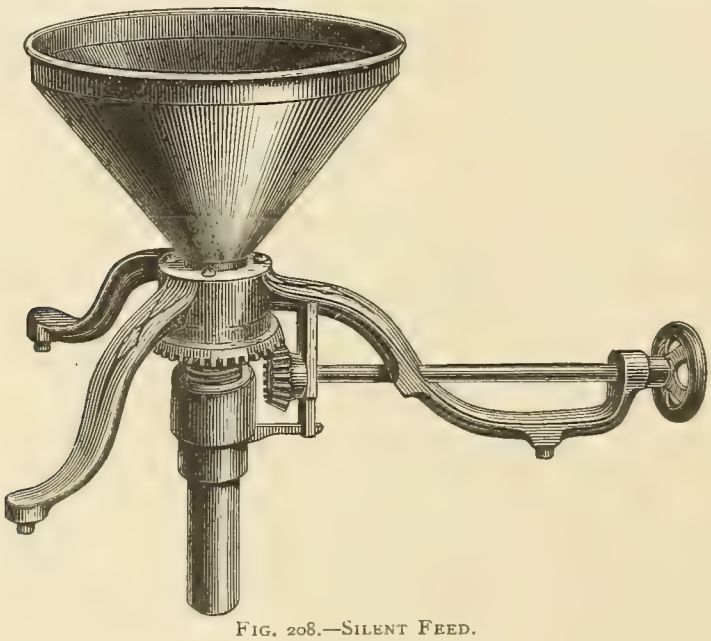

FIG. 208.—SILENT FEED.

lean either toward or from the post. This point being found, the plane which passes through this and parallel with the face of the burr will divide it into

two portions of unequal height but of equal weight. The point of suspension should be made about a quarter of an inch above this plane.

The Damsel.—The damsel is shown in Fig. 205 in one form, and in Fig. 206 in another. Fig. 207 is another form of damsel.

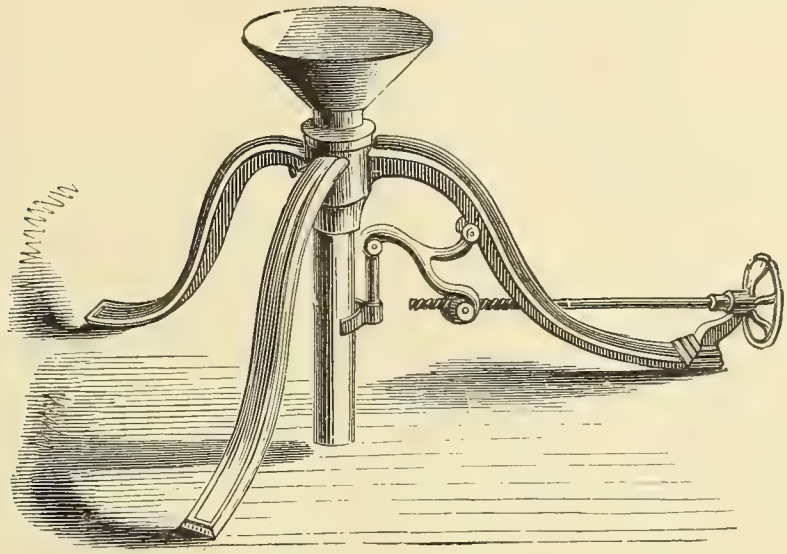

FIG. 209.—SILENT FEED.

Feeders.—Flour middlings and meal are difficult to feed with regularity, because they have a choking tendency. To prevent choking, and to insure regular feed, it is sometimes necessary to have a positive mechanical feeder. A loose rod of wood in the eye, extending up into the hopper, often

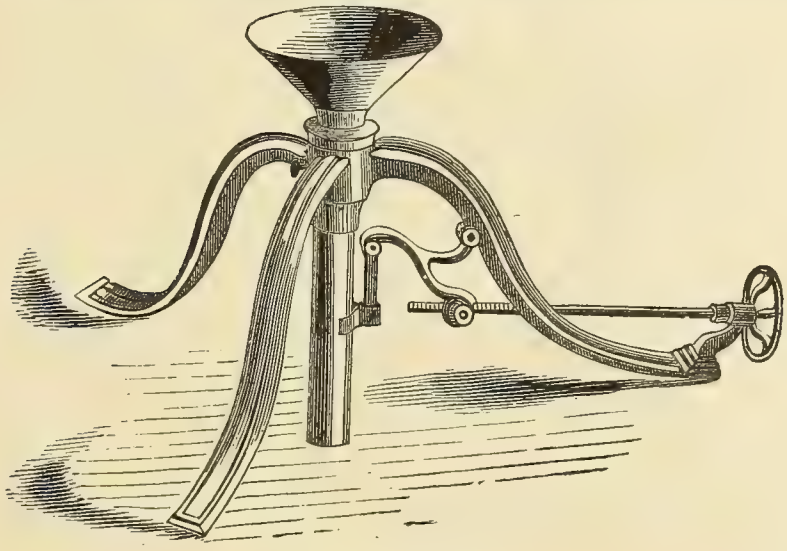

FIG. 210.—SILENT FEED.

serves to keep loose choky material from clogging, as it rotates and stirs the stream.

Fig. 208 shows a silent feed, in which the regulation is effected by means of bevel gears. Figs. 209 and 210 show other forms of silent feed.

In the silent feeder the grain is admitted from the bin or stock hopper through a pipe open at both ends, the lower end being in close proximity to the saucer on top of the rynd, the speed being regulated by a small hand-wheel, which being turned to the right or the left raises and lowers a small pin by which the opening between the mouth of the feed-pipe and the saucer

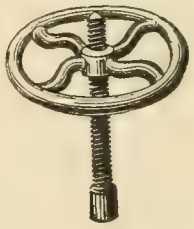

FIG. 211.—LIGHTER SCREW.

will be increased or diminished. Sometimes the feeding pipe is fastened on the curb by a tripod. It feeds more regularly than the damsel (or dansil).

The damsel, while it is certainly an improvement over the clapper and shoe, makes a great deal of noise, and is otherwise inconvenient.

Automatic Stone Lift.—This consists of a cord having on it a series of leather discs and suspended in the hopper. This cord passes over several pulleys, and is attached to a weighted lever, one end of which has a ratchet tooth engaging with a wheel on the same axis as a drum around which passes

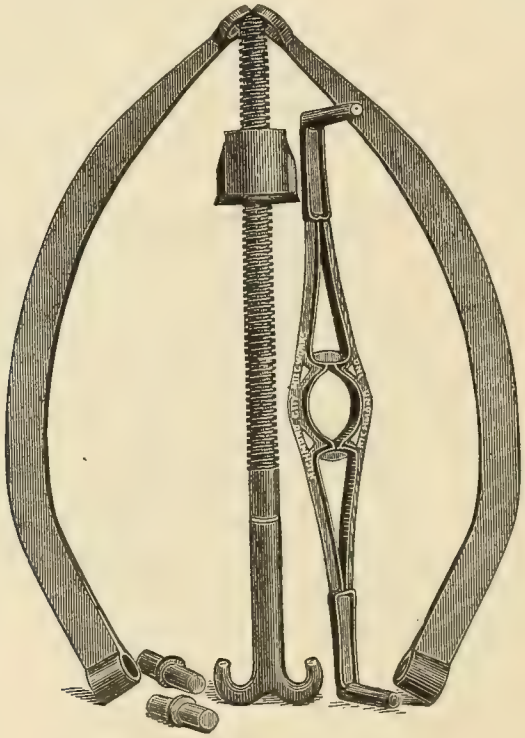

FIG. 212.—CRANE IRONS.

a chain pulling upon the lighter rod. A cord passing around the wheel carries a weight sufficient to lift the stone. As long as the stream of wheat keeps running, the hopper, the pulley, and the leather discs keep the tooth lever engaged with the ratchet; but when the feed stops the lever is de-

tached and the weight lifts the stone free and clear so that it cannot destroy its face.

Fig. 211 shows the ordinary form of lighter screw.

Iron Burr Crane.—In place of the ordinary burr crane of wood, we recommend the light and strong portable iron device shown in Fig. 212, made by the Richmond City Mill Works, Richmond, Indiana. These hoisting irons are well proportioned, strong and durable. The screw is made of the best wrought iron, and the bales and wrench are of malleable iron.

Oiling Mill Spindles.—The plan of putting a string around the spindle has the disadvantage that there is danger of having to take up the mill to put in a supply of tallow or oil. A better way is to guide oil through a small pipe from the outside of the curb down below the husk frame and bottom stone, thence with an elbow toward the bush, just below the bush; thence through a hole or opening in the bush upward to nearly a level with the top of the bush, where a groove is cut just deep enough to admit the discharge end of the little pipe to sink below or even with the level of the top of the bush, and not be in the way of anything which might be used as a bush cover to keep out dirt and trash.

Fitting a New Back.—When the back breaks and flies off in running, or the stone is not heavy enough, a new back must be made. To do this, block the stone up, face downward, evenly, solidly and perfectly level.

Pick and scrape off the plaster down to the face blocks. Wash these and soak them well with water.

During this time have some clean bits of burrstone soaking.

Mix plaster-of-paris with clean water and a slight proportion of glue. Pour this upon the dampened stone back and rub in with the hand.

Place small spalls over the joints of the blocks with a stiffer plaster. Build around the eye and verge walls of burrstone, four and five inches high. To make the stone heavy, take small pieces of iron, well washed and free from rust or grease, lay them evenly around the stone between these walls, and pour in thin plaster until the surface is nearly level with the two walls.

If the stones do not need weighting, use burr-spalls instead of iron.

Keep on building the walls until they are within two inches of the thickness your stones are to be, keeping the eye wall two inches above that around the verge. Fill in the space with stones, pour in plaster nearly level with the walls, and leaving a rough surface.

When this has dried and perfectly set, rest the stone on the edge and plaster around the edge. When thus cased, lay the stone on the cockhead with the driver off, rest the spindle and balance the stone. Have a tin made the size and reaching to the proper height the stone is to be at the eye. Fasten this down. Fasten a hoop of wood or iron around the verge so as to reach up to the desired height at the verge.

Within this hoop and the cracks around it, pour in thin plaster with plenty of glue water, which will retard the setting, and, with straight-edge resting on the hoop and the tin, and working the plaster with a trowel, turn the stone. Make the surface of the back even and smooth. Take off the

hoop and smooth the back and edges. Lower the spindle till the runner lies solid. Heat the iron band or hoop, put it on and cool it with water. The best plaster-of-paris must be used. Many prefer the use of sulphur (brimstone) to lead, as it is not poisonous.

In backing up millstones, or in making a new back, trouble is sometimes experienced by the very short time that elapsed before the whole back sets fast and hard. To prevent the plaster from setting too fast, it should be mixed with glue or with isinglass, or, if this is not at hand, with milk. We have not tried glycerine, but think that it would retard the drying. Mixing the plaster with urine instead of with water answers. Alum in the plaster makes it finish close and hard.

Cost of Building Up.—The cost of building up is considerable. It is considered good work to set two blocks a day. Averaging fourteen blocks to a stone, it will take a man nine days to do the work well.

Allowing eighteen dollars ($18) a week to the builder, the building of one stone would cost twenty-seven dollars ($27).

The block dresser, getting two dollars a day, can dress four in a day, making seven dollars more. Hoops and plaster in backing up, together with labor, will cost five dollars, and labor eight dollars. Facing and furrowing would cost about twenty-five dollars ; making in all seventy-two dollars for building and finishing one millstone.

CHAPTER XXIV.

VARIOUS MILLSTONE DRESSES.

The Dress—Choice of Dress—Path of Material—Elements of Dress—Eye—Bosom—Face—Proportion of Land and Furrows—Duties of Furrows—Number of Quarters—Number of Furrows—Outline of Furrows—Circle Furrow—Hollandish Circle Dress—Improved Circle Dress—Logarithmic Spiral Dress—Angle of Furrow Crossing—Laying Out Circle Furrows—Direction of Furrows—Draft—Depth of Furrows—Furrow Section—Smoothness of Lands and Furrows—Old Quarter Dress—The Hughes Dress—Compromise Dress—Pennsylvania and New Jersey Dress—Old Style Equalizing Dress—New Style Equalizing Dress—Combination Dress—Dickson Dress—Southern Dress—Jones Dress—Bowman Dress—Arndt's Dress—Ward's Millstone Formula—Dressing for Regrinding—Other Dresses (for Old and New Process, for Middlings, for Corn, for Wheat, &c.)

The Dress.—Milling being as yet so much more of an art than a science, no definite rule based upon scientific principles can be laid down to determine the exact dress which can be given for working the various kinds of material and turning out the various products which come within the province of modern milling.

Upon no part of the work in the modern mill does the quality and cost of product so materially depend as upon the dress of the burrs, where burrs are used.

While we cannot give definite rules for each particular case, we can lay down what is the average and recommended custom of skilled millers, which will do excellently well for others to follow until exact rules are determined and the art of millstone dressing elevated to a science. One thing is certain —no matter what quality of face, what amount of bosom, what draft or section of furrows is employed, the work must be perfect of its kind. The implements employed, and the methods of using them, will be separately treated in another chapter. In this chapter we shall consider the various elements which enter into the millstone dress, without regard to the manner of dressing.

In the preparation of this chapter the author has relied very largely upon the opinions and experience of successful millers in all sections of this country and Europe. This being the case, he has largely quoted from their letters or published remarks without attempting to reconcile apparent discrepancies or contradictions; because, in this as in many other instances where opinions apparently differ, the variance of unobserved or unrecorded conditions would account for much diversity of successful practice.

The author has simply undertaken to lay down certain principles upon which careful and intelligent observation may be based and recorded.

Choice of Dress.—The stone maker or miller must keep constantly in sight two things: First, the conditions that must be fulfilled by a perfect dress, and, second, the factors to be considered in order to obtain the desired conditions.

Referring to the first element, the quantity of the grain at the eye must be proportional to the exit of meal at the skirt; and during the comminuting process, the grain must not be rubbed nor crushed, but cut. Under the second head we have to consider first which way the stone runs; second, its diameter; third, its peripheral speed; fourth, the structure and material of the stones; fifth, the nature of the material to be ground; sixth, the method of milling employed.

It is comparatively easy to determine what conditions a proper dress should fulfil, but it is a much more difficult task to describe how these conditions may be attained. The direction of motion is, of course, regulated by the buyer, and gives no trouble, but it would be by the merest chance that the burr maker could dress a stone that would perfectly fulfil the latter four conditions. The question might be asked, is there any one universal dressing which under all circumstances would satisfy all conditions? Plenty of millers have offered dresses which are calculated to grind anything under almost any condition, but the eagerness of mill-owners in taking them out generally comes fully up to the zeal with which their originators offer them. To many, if not to most millers, it will have happened in practice that two pairs of burrs, equal in size, dressed alike, apparently identical in quality and material, and running at the same speed, gave entirely different results, although handling grists of the same grain. Although the distance of the stones may be the same, one may grind soft and the other hard. A moment's reflection on this point should satisfy the miller that there can be no one dressing for all conditions. In many cases mill furnishers have had burrs returned to them as of inferior quality when the fault was not in the quality of the stone, but in the dressing.

There are some combination dresses, good for fair work with almost any material or work that may be demanded in any one mill; but as good work cannot be done in this way, as by noting what will be most required and giving the dress specially adapted for those conditions.

We advise our readers to draw the various millstone dresses in circles about six inches in diameter, one on card-board and the other on transparent linen or paper, and reversing the latter and sticking a pin through the centre of both, note the crossing of the furrows. If this does not convince them that the ordinary quarter dress, with the parallel furrows, is imperfect, especially with few quarters on large stones, it will at least set them thinking.

Path of the Material.—The path of the material is different in under-runners from what it is in upper-runners, and different in vertical mills from either. In the first case the material falls on a "live" surface; in the second, on a motionless one; in the third, on neither, strictly speaking.

In the upper-runner the path, if the furrows did not change it, is stated by KICK to be a spiral; in the under-runner, the involute of a circle.

In Fig. 213 the lines A and B represent the supposed paths of the material on an upper-runner, as traced out by two noted British millers. They are widely different, and yet the probability is that each is very nearly right, for the conditions which its maker had in mind.

"In under-runners the path made upon the upper, or stationary stone, will be according to the involute of the curve $r = \frac{30^2 gc}{3.1416^2 \times T^2}$;" c being the friction coefficient, $r = 0.16$ inches $= 6.3$ inches, $g = 9.088$ metres $= 29\frac{3}{4}$ feet.—(KICK.)

Elements of the Dress.—These are the eye, bosom, and grinding surface or face proper; the latter being divided into land and furrow; and the furrows varying in duties, arrangement, number, outline, direction. length, draft, width, depth, section, and surface.

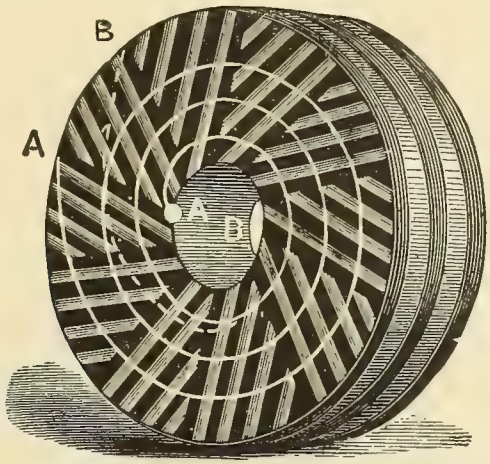

FIG. 213.—SUPPOSED PATH OF MATERIAL.

Eye.—The eye is strictly an element in the dress, because it offsets or modifies the action of the furrows. The larger the eye and the greater its "flare" or taper downward and outward, the easier the feed and the less bosom and draft necessary.

Bosom.—The bosom is for the double purpose of allowing the feed easy entrance and of giving the grinding or granulating face of the burrs a gradual action on the material being reduced or otherwise operated upon. The circumference of the eye being so much less than that of the skirt, the

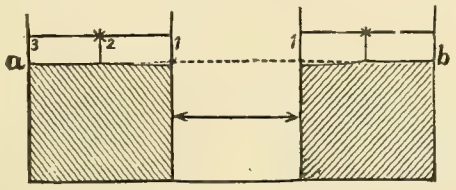

FIG. 214.—SECTION OF BURR.

stones must have a greater distance between them at the eye than at the skirt, in order to give the same annular area or channel for the material to pass in. The area and the depth of bosom vary greatly. The author believes that a wide, very shallow, perfectly even bosom, with well dressed surface, will be found advantageous in almost all styles of milling; the furrows extending into the bosom.

"In olden times the bosom was very much used. Afterward the number of quarters and leading furrows was increased, and the short furrows cut

through into the leaders, which, of course, increased the draft, and the bosom has been reduced to the thickness of a sheet of paper."

The Face.—The face or plane granulating surface proper, may comprise nearly or all the area of the stone from eye to skirt; or it may be a mere strip next the skirt. It may be furrowed or not; generally the former.

Proportion of Land to Furrows.—We have before us an account of a German miller, who, on finding that his stones would heat, reduced the breadth of the grinding surface from 25–132 of the diameter of the stone to 24–132, then gradually to 20, and the smaller the direct grinding surface, the better the results until he went below 20 to 18 or 19, which gave worse results, 20 giving the best. In the first case the temperature was 25° to 30° Réaumur = 88¼° Fahrenheit to 99½° Fahrenheit. With 20–132 land it was only 8° to 10° Réaumur = 50° to 54½° Fahrenheit, and the capacity was increased 80 centners more per day."

"The rule two-third furrow surface to one-third land surface is good for close stone and hard wheat. An open stone will stand more land, and soft wheat more even furrows."

"Too much face cuts up the bran and causes specky flour. Too sharp or too rough a stone will do the same thing. When there is too much face the material may be ground two or three times before it leaves the stone."

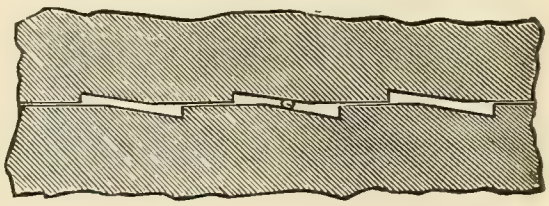

Fig. 215.—Grain of Wheat in Furrows.

"One reason for change in millstone dress may be the increased power now applied and greater capacity for each run. The size of the burrs has been very much reduced. Whereas stones used to be from four and one-half to six feet in diameter, they are now from four and a-half down. More being required in a stone, of course less of it can be used in bosom."

"The capacity of burrs depends, not on their diameter, but on their superficial feet of face. In order to grind a given quantity with large stones, fewer revolutions will be needed and a larger driving pulley required, while small stones of half the superficial face do the same work as large ones with twice as many revolutions and half the purchase. They have the disadvantage of having to do the same amount of work on half the surface, so that their advantage resolves itself down into their decreased cost and space and handling."

Duties of the Furrows.—Here opinions differ. If furrows did nothing but admit air to the burrs, it would be cheaper to drill holes through the burrs, and then there would never be any furrow dressing required. They certainly perform at least four offices: granulation, cooling, distributing the chop between the faces, and carrying out; but their action is very different from what is generally understood concerning them. In proof that

they are not essential, stones are run (though rarely) without furrows, and the granulation, distribution and carrying out have not been stopped, though the chop was unduly warm; and in regard to the carrying out by "shears-like action," tests have been made with the furrows reversed, and not greatly affecting the capacity of the burrs.

In order to show that the furrows do not perform all the office of distribution or carrying out, we may refer to some experiments made by Schmidt, in which the runner was reversed, there being no great difference in the resulting material. Hlavac made some tests with a burr-stone 1.1 metre = 43.30 inches in diameter, having twelve quarters; the draft circle being 8 centimetres = 3.1496 inches in diameter, and there being two short furrows in each quarter. The eye was 26 centimetres = 10.2362 inches in diameter, and the breadth of the proper grinding face was 19 centimetres = 7.4803 inches.

The furrow section and the bosom when right, and the balance perfect. In the upper stone were three wind furrows. With 300 litres of ended wheat (Hochschrot) product making the first reduction was, with the runner turned in the proper direction $12^2 \times 5.5$ kg. of break flour of different kinds, in all 19.5 kg. = about 6 per cent.; 10.2 kg. of fine middlings, 22.8 per cent. of coarse middlings; the temperature of the chop being 23° C. = 73.4° F. With the runner reversed in motion, the quantities of break flour of three grades was 17.3 and 5.8, in all 25.8 kg., = about 8 per cent.; there were 8.8 per cent. of fine middlings and 30 per cent. of coarse middlings; the temperature of the chop being 25° to 26° C. = 77° to 78.8° F.

This shows that while the ordinary run of burrs will do different work with the furrows reversed than with them running in proper direction, and there will possibly be more break flour, the influence of the furrows is not so important as is ordinarily supposed.

Number of Quarters.—As regards the number of quarters and the number of short furrows in each, we have a standard which can be maintained that for good dressing the essentials are to have many principal furrows, few secondaries and a great number of quarters. It is very seldom that we find more than three or less than two short furrows in each quarter; but it should be different. We often see sketches and plans of dresses with five secondaries and one leader, that is, six furrows to the quarter, making it appear as though there were more room on a little strip of paper than on a large stone. Now, why should there be many quarters with few secondaries rather than few quarters with many furrows? If we take a dress of ten quarters, each having one leader and five secondaries, the secondaries lying parallel with the leaders, it is clear that each of the short furrows has a separate draft circle. Now the angle of intersection of furrows depends altogether upon the diameter of the draft circle, so it is not difficult to comprehend that the intersecting angle of the shortest secondaries must be the most obtuse, and that of the longest secondary the most acute. The principal objection to this style of dress is that the draft circle of the outer secondary fails to fall into the grinding surface of the stone, so that the grist must be drawn far out without reduction.

Many experienced millers say that two furrows in each quarter is the proper number, and this independent of speed, diameter, or material of the stone or the nature of the grist.

A porous stone does not need so many furrows as a close new stock burr.

The more quarters the more even the draft of the furrows will be, one with the other. There is little or no use in having one furrow with four-inch draft and another with ten to twelve. Yet there is this to be said, that if there be too many furrows running directly from the eye, they will be apt to chop the bran up too much. This, however, can be remedied by bosoming. There is this advantage in having more furrows in the skirt, that there the speed and friction are greater, and more cooling surface is needed.

Our own opinion is that the "quarter dress" proper is a barbarism, as generally applied; and that when we consider the course of the grain or other material, in its outward progress from eye to skirt, we must incline to such dresses as will give all the furrows on each stone, as far as possible, the same draft: this entirely independent of the question as to whether or not the angle of crossing of bed and runner furrows shall be the same for all points along the length of the furrow. The "quarter dress" may be abolished and still leave free choice between straight, bent or curved furrows; between furrows all of a length and those of varying length; between those having the same crossing angle* all the way out, and those having the crossing angle vary at different distances from the eye.

The writer's objections to the quarter dress are based on analogy. Evidently the fewer quarters the greater the disproportion between the draft of the leaders and that of the secondaries, in stones of equal diameters.

Number of Furrows.—Evidently a given area in furrows may be got by having few wide furrows, or more narrow ones of proportionate width; by a few long furrows, or more short ones of proportionate length. Here again the questions of stone diameter, material operated on, and product desired, come in, complicated with details concerning the methods of "ventilating" the stone, and the bosom, hardness and porosity of the stone. Modern tendency seems to be to an increase in the number.

Outline of Furrows.—Furrows may be circular, rectilinear, bent, or spiral. "The first form has great drawbacks, and must yield before the widely-extended straight furrows, and the last is complicated and has not at the present time secured a reception. Beyond the question of whether the furrows shall be circular, straight or spiral, comes the question of leaders and secondaries. The secondary furrows must be either tangential to the same draft circle as the leaders, or parallel with the leaders themselves. The value of the secondaries is in no sense inferior to that of the leaders. Secondaries parallel to the leaders are much more common than those striking from the same draft circle. But to discuss which mode is the best of the two is a rather difficult matter."

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*"Crossing angle" means the angle formed by any furrow in one stone, with one in the opposite stone. With curved furrows the angle is measured between the tangents at the point of crossing.

"A curved dress requires more power to drive the stones than a straight one. As regards curved dress, the skirt wears lower than the breast, and the heat caused by the great pressure affects the quality of the flour. These figures refer to a 4½-foot stone of close texture, running one hundred and fifty or one hundred and sixty."

FIG. 216.—BENT FURROW.

It is hard to discuss the outline of furrows without going very extensively into the question of draft; because straight furrows (unless radial, a rare form) invariably have a greater crossing angle at the skirt than at the eye; furrows which have the arc of a circle as an outline may have either an increasing or a decreasing crossing angle, according as they are laid out; and

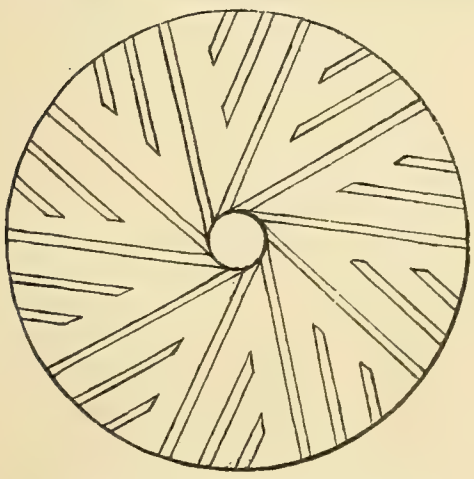

FIG. 217.—STRAIGHT QUARTER DRESS.

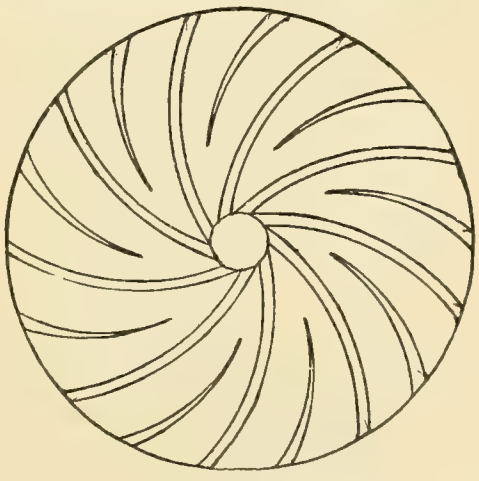

FIG. 218.—CIRCLE QUARTER DRESS.

the peculiarity of the so-called "spiral" furrow (generally a "logarithmic spiral") is that the crossing angle is the same all the way along its length.

It may be said, however, in general terms that the straight furrow is the most common and the easiest laid down and put in, while the logarithmic

spiral is the most difficult to design and to make. Under the head of special dresses, furrows of various outlines will be discussed in detail and illustrated.

Circle Furrow.—The "circle furrow" has one or both edges a true circular arc. It is sometimes incorrectly called the "Sickle Dress;" but this latter term should correctly be applied to a curved furrow having varying curvature. The circle furrow may be varied by the proportion which its radius bears to the semi-diameter of the stone, and by the distance between the centre of the stone and the centre from which the furrow is struck.

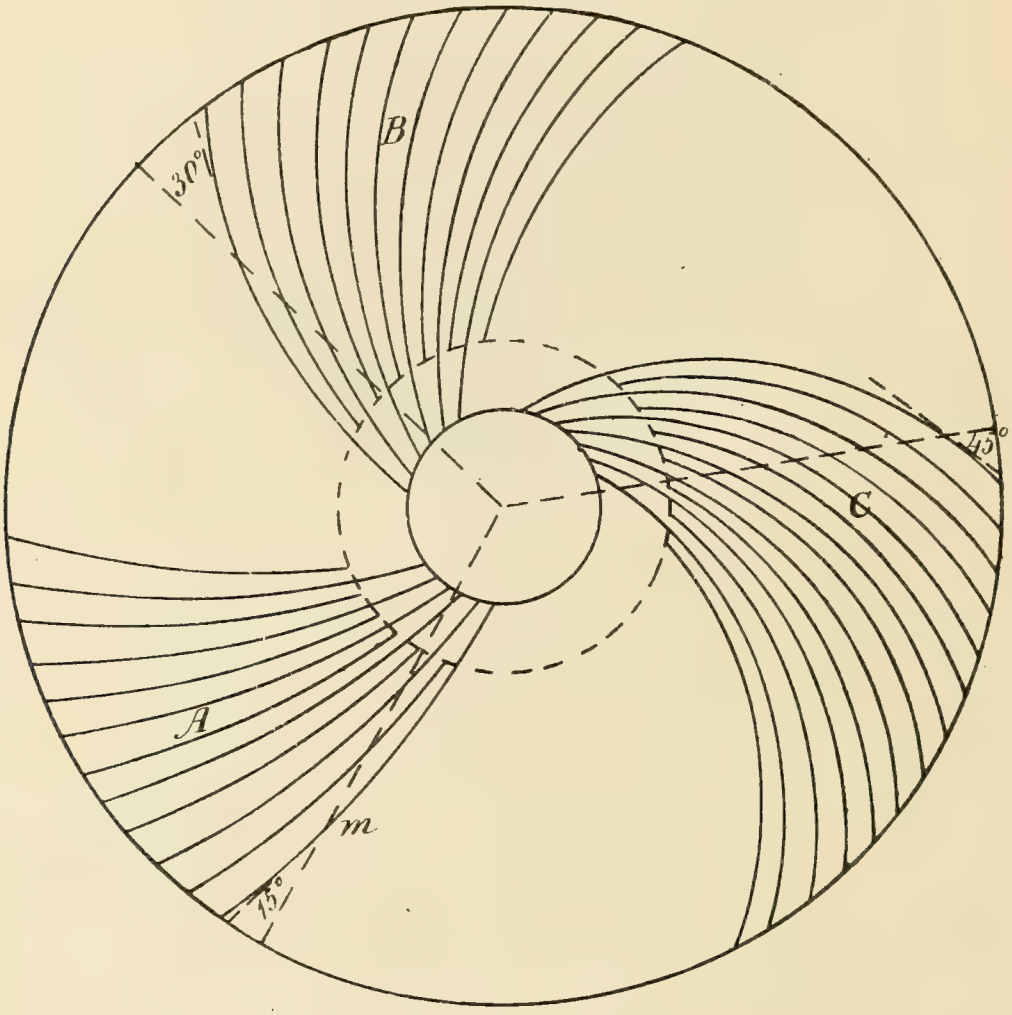

FIG. 219.—LOGARITHMIC SPIRAL DRESS.

The longer the radius of the furrow circle, the nearer it approaches in its action to a straight furrow, and the more the crossing angle increases as we near the skirt.

The greater the distance between the centre of the stone and the centre from which the furrow circle is struck, the less the crossing angle at any given point, and the less the increase of the crossing angle as we go from eye to skirt.

It is desirable in circle dresses to have the crossing angle as great as possible, especially at the eye, to facilitate the feed.

Hollandish Circle Dress.—This dress has no quarters; all of the furrows are alike; the circle radius is from $\frac{4}{5}$ to $\frac{7}{8}$ the semi-diameter of the stone, and the furrow circle starts at the centre of the stone. The crossing angle at the skirt is 77° where the furrow radius is $\frac{4}{5}$ that of the stone, and 69° where it is $\frac{7}{8}$ the stone radius.

Improved Circle Dress.—An improved circle dress having all the furrows alike has the furrow radius 0.633 that of the stone radius, and the distance of the centres from which the furrow is struck is 0.62 the stone radius. This gives a crossing angle of 110° at the skirt. With furrow radius

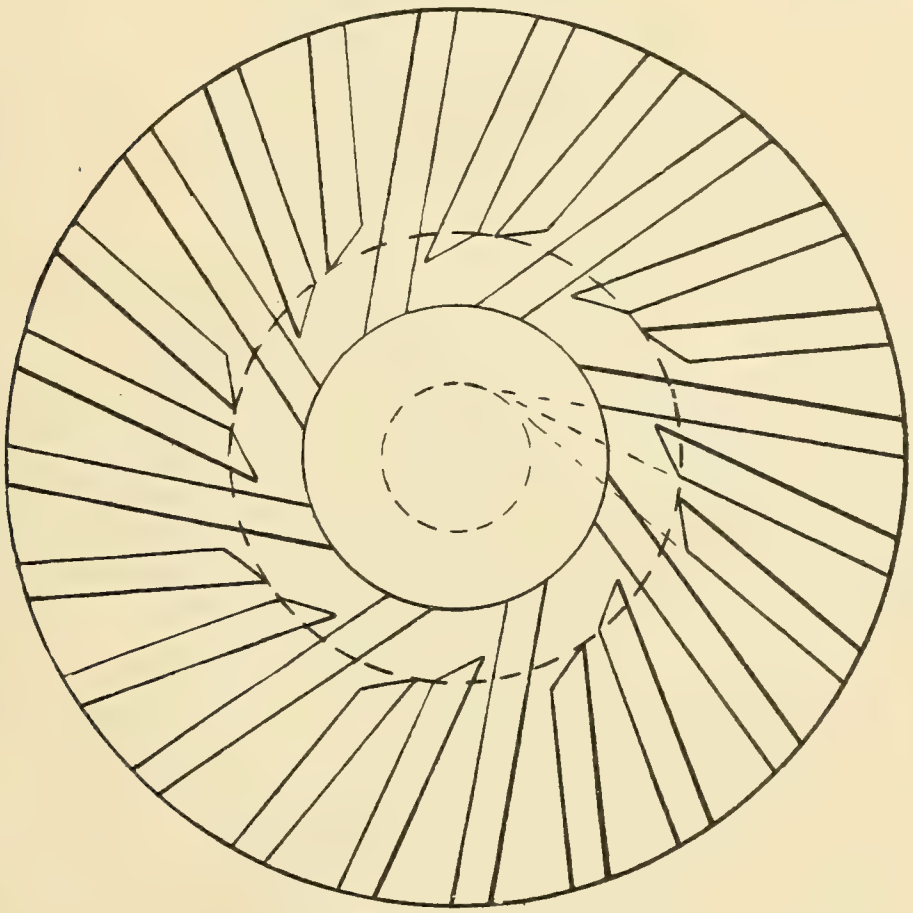

FIG. 220.—FURROWS WITH EQUAL DRAFT.

of 0.76 the stone radius and distance from stone centre to centres of furrows of $\frac{11}{16}$ the stone radius, the maximum crossing angle is 86°.

Logarithmic Spiral Dress.—This has the crossing angle constant all the way out, and generally all the furrows are alike in length as well as in curvature. To construct it, mark out a number of close and equi-distant radii, and having laid out a furrow line from one, with the desired draft, measure the angle between this and the radius it starts at, and then, where it cuts the second radius, make a second line (having more draft) which has the same angle with the second radius. In this way proceed, and then modify the broken line into a curve.

Fig. 219 shows logarithmic spiral furrows of three different drafts. The furrows A make a constant angle of 15° with every radius; those at B, 30°, and those at C, 45°. There are no parallel furrows; all of a kind have the same draft.

Angle of Furrow Crossing.—The various kinds of dresses may be divided into the following classes: (1.) Those in which the angle of furrow

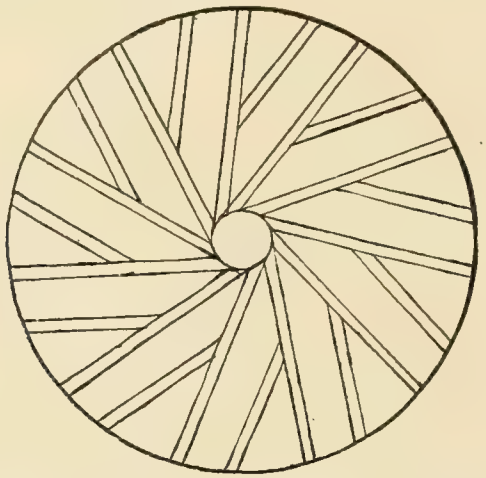

FIG. 221.—QUARTER DRESS—WRONG ARRANGEMENT OF SHORT FURROWS.

crossing increases toward the skirt; in other words, the draft of the outer portion of the curve is greater than that of the inner. In these we may class the old circle dress and the improved old circle dress. (2.) Dress with a constant crossing angle. In this we include the logarithmic spiral dress (Fig. 219). (3.) Those in which the angle of furrow diminishes toward

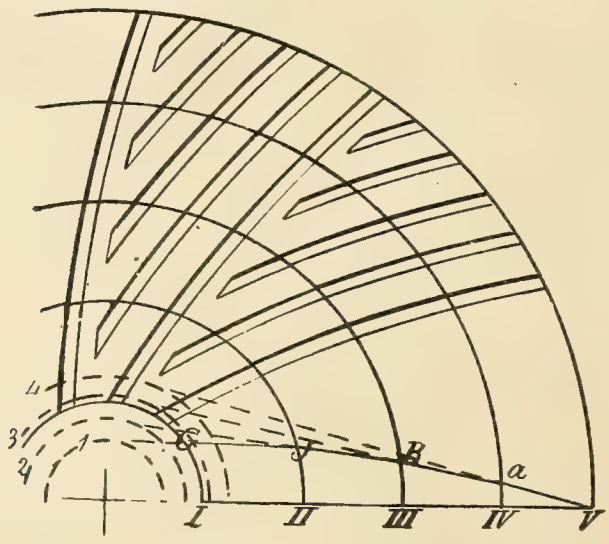

FIG. 222.—EVANS DRESS.

the skirt. In this class we find all straight furrows, the furrows of the new circle dress, and the Evans dress. See Fig. 222.

Old "quarter dresses" divide themselves into two groups—those having all the furrows of the same draft, and those having greater draft for

the short furrows than for the leaders. In Fig. 220 there is shown a quarter dress, in which the skirt furrows have the same draft as the leaders. Those in which the short furrows are parallel to the leaders are illustrated in Figs. 217, 221, &c. It must be noted that the short furrows must never be prolonged into the next quarter or leader.

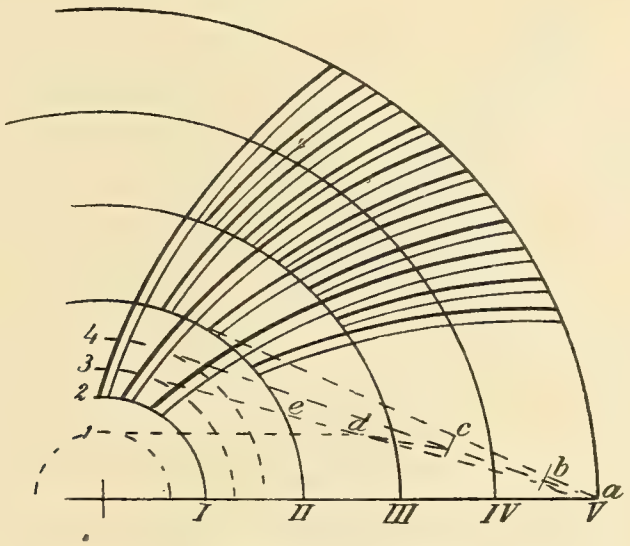

FIG. 223.—WIEBE'S DRESS.

The Evans Dress, Fig. 222, is a curved dress in which the leaders have greater draft toward the skirt than at the eye—the short furrow being parallel to these. In Wiebe's Dress, Fig. 223, the leaders are curved and have increasing draft; but the short furrows are curved exactly like the

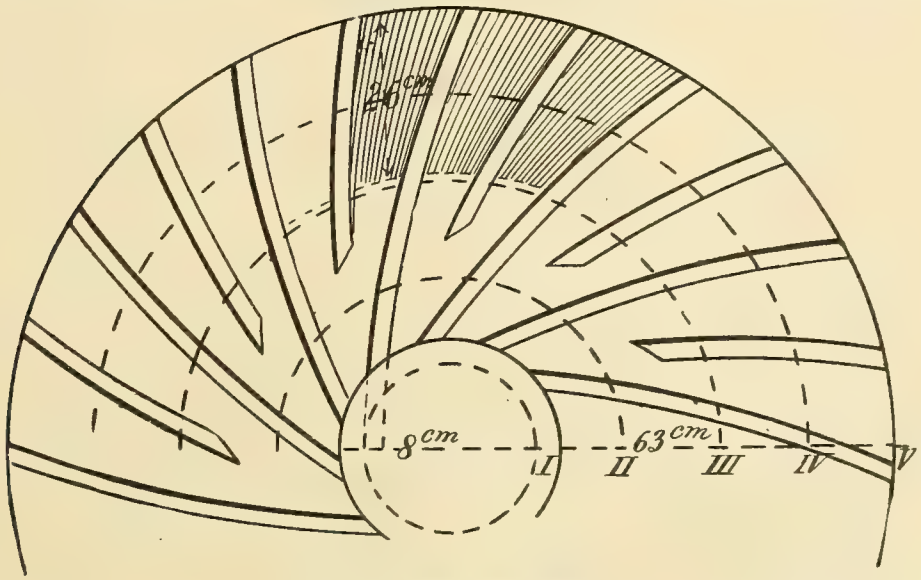

FIG. 224.—NEW CIRCLE DRESS.

leaders, except that they are not prolonged in the eye. In the new circle dress, Fig. 224, the draught diminishes toward the skirt instead of increasing. All the above-named dressers are for upper-runners, and then we have (4) dresses for under-runners.

In any circular dress in which the radius of the furrow is equal to the distance of the middle point of the furrow from the centre of the stone, the sine of half the angle of crossing of the furrows is equal to the *radius vector*, and the crossing angle increases toward the skirt.

The angle of furrow crossing can be smaller with under than with upper runners; large crossing angle not being required at the eye, in order to permit the feed to enter easily and rapidly. The furrows of an under-runner should make an angle at each point, with the path of the chop, greater than the friction angle of the material (which is about 37°), the sides of the furrow being steep. If this is not observed a large part of the material will be unbroken. Where the furrow has a perfect feather-edge, the material

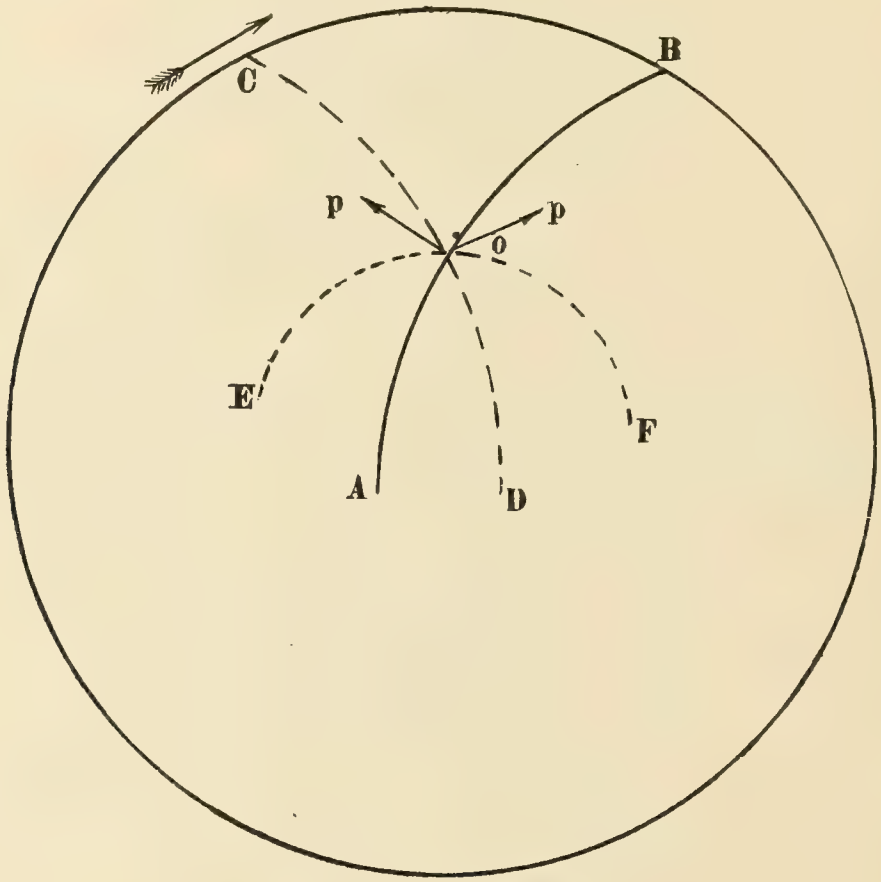

Fig. 225.—Crossing of Furrows.

will follow most nearly the true involute path. The old circle dress should in no case be employed for under-runners.

Schmidt announces that the distribution of the chop by the working together of the furrows, tracing the material from the eye toward the skirt, is of considerable consequence, and announces that two curving furrows, which working together must never cross each other in two points at once. He explains these by diagrams, which we reproduce here. Referring to Fig. 225, A B is a curved furrow in the bed-stone (we speak of upper-runners now), and C D, shown in dots, represents the furrow in the upper stone or

runner; the arrow, showing the direction of motion of the dotted furrow line, C D. It will be seen that these cross at the point O. There are two tendencies for the pass of grain: one to go toward P by the action of the furrow of the runner, and the other to go toward P′ by the action of the furrow in the bed-stone. Referring to Fig. 226, where the letters are the same for similar things, the line *p* is the average or resultant between the force X, perpendicular to A B, and the force *y*, tangent to A B. In order that distribution or carrying out by the furrows may take place, it will be necessary that *y* shall be in the direction of the skirt, which will not be the case when the curves cross each other in two places, as shown in Fig. 227. The angle to *t*′, made by the tangent to the two curved furrows, is the crossing angle of those two furrows at that point. The pressure *x*, multiplied by the

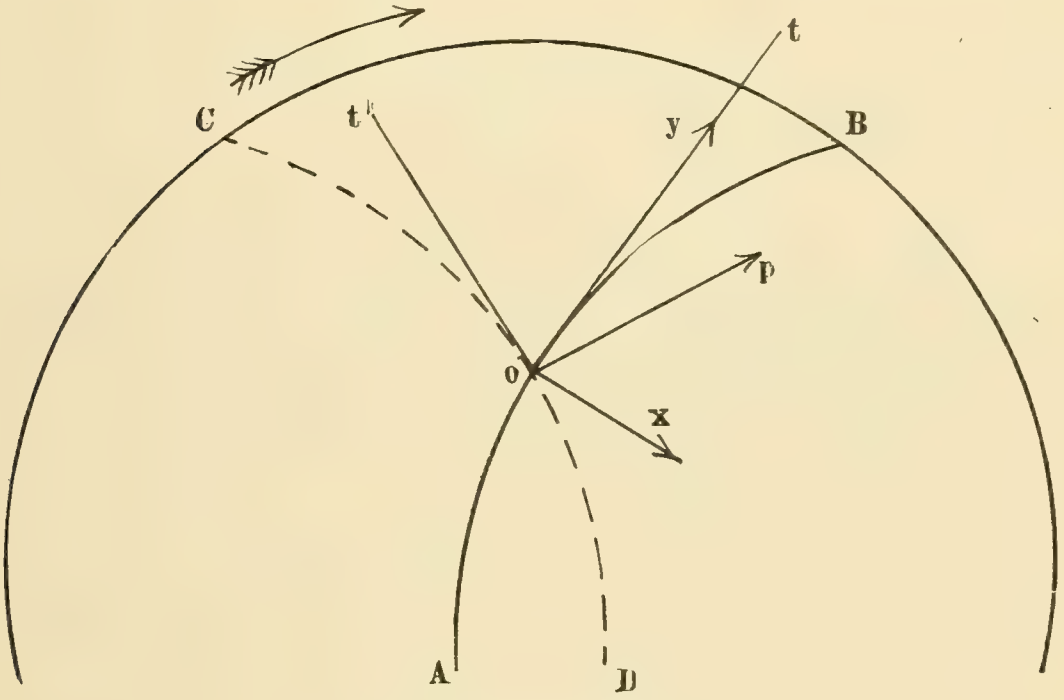

FIG. 226.—CROSSING OF FURROWS.

coefficient of friction of the chop upon the stone, will give the power required to carry the chop out to *y*. Where the distance *y* is equal to *x* times the coefficient of friction, then both the forces, *x* and *y*, will have equal force, and there will be no crowding of the particles in the direction *y*. Schmidt then says that for a given angle of crossing of the furrows, the tangent of angle is equal to the coefficient of friction of the chop upon the stone (this angle will be called the friction angle); there will be no distribution by the furrows, *y* being equal to *x* times the coefficient of friction. If the crossing angle of the furrows becomes greater, then this force *y* will increase and *x* will be less. This will give a general rule concerning the distribution of the chop by means of the furrow alone, that the greater the angle of crossing of the furrows, the greater their action in the distribution of the chop.

Where the angle of crossing is less than the friction angle, then the furrows will not act to distribute or push out the chop, but only to cut or break the material. Schmidt concludes that for the distribution of the chop by the crossing of the furrows the crossing angle of the furrows

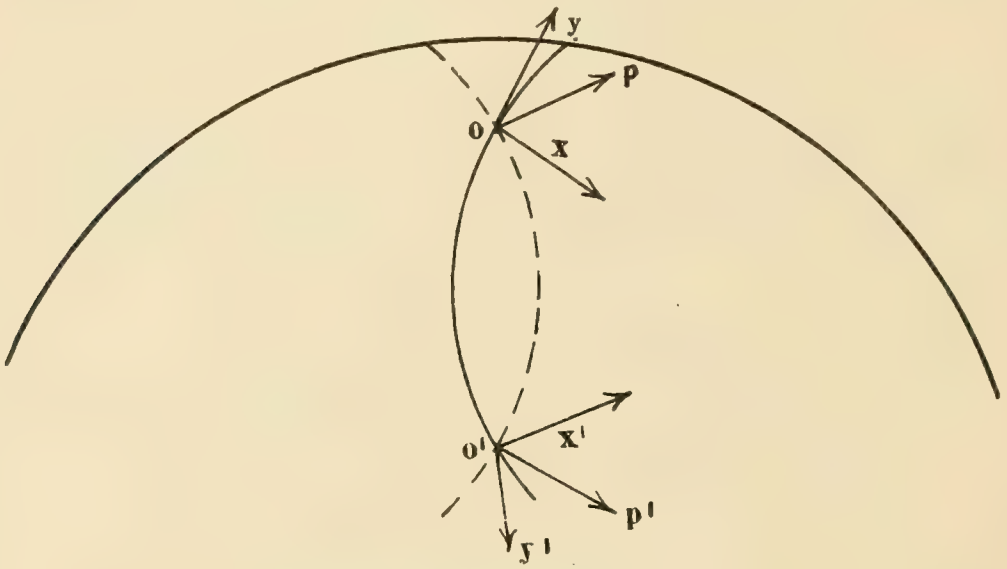

Fig. 227.—Wrong Furrow Crossing.

must be double the friction angle. The friction angle of the chop upon the stone face is about 37° to 38°; and this would point to a crossing angle for the furrows, of about 75°. But the experiments already quoted, of the runner working backward without much affecting the quantity of the chop,

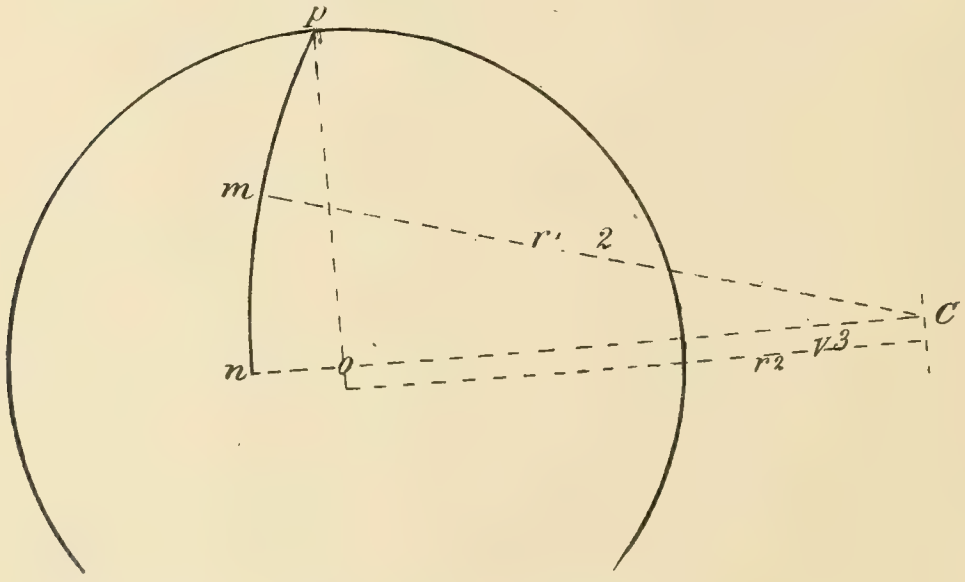

Fig. 228.—Laying Out Circle Furrows.

show that the influence of the furrows in carrying out the chop by their working together is of very little importance; this being due more to the centrifugal force and the ventilating action of the furrows than to the shearing action of the furrows.

Laying Out Circle Furrows.—In laying out circle furrows the lengths OC, CM must be considered. In one dress recommended, where R represents the stone radius, say 1, r_1 the furrow radius, is $\sqrt{2} = 1.414$, and r_2, the distance OC of the stone centre O from the centre C the furrow is struck from, is $\sqrt{3} = 1.732$. See Fig. 228.

Direction of Furrows.—"To prevent short furrows running the wrong way, the following rule must be observed: All of the short furrows in a quarter must lie not behind the leader, but invariably before the leader belonging to that quarter.

The advertisement of the French stock company of the Bois de la Barre, in La Ferté-sous-Jouarre, appearing in every number of the *Deutschen Mühl-anzeiger*, attracts attention from the fact that the illustration—a dressed burr—shows the fields with the furrows running the wrong way. Of course, we cannot say that this firm would reverse the short furrows in this way on the real stone, still it must cause astonishment that such an important millstone factory should employ an incorrect picture. Even mill architect Haase, of Breslau, in his work on practical milling, shows a dress very much like a reverse one; he calls it the *Felderwischschärfe*, but I never heard of any mill employing it."

Draft.—When it comes to the question of dress you will find that more millers give one inch draft to the foot diameter than any other draft; and they are very particular about this one inch draft to the foot. It does not seem to make much difference if there is a feather-edge or a step, a smooth or a rough surface, or what the depth is, or why the angle should be rounded or not, but they stick to the one-inch draft for any or all conditions, no matter if the speed is as low as one hundred and twenty-five or as high as two hundred to the minute.

Both the centrifugal force and the air current are greater in the case of fast running burrs than in slow; so in the latter case there must be more draft than in the former. The draft may be corrected somewhat by the depth; if too slight, the furrows may be deepened, if too great let them become shallower.

Open porous stones require less draft and fewer quarters, because care must be taken to give them plenty of face. Hughes' rule for draft is, for the straight dress in close stone, an inch to the foot of diameter; for curved dress three-fourths of an inch. The dress should be such that in grinding the stone should receive a proportionate quantity on its entire surface from the eye to the skirt. In obtaining this we encounter this difficulty, that the circular motion increases from the eye to the skirt. It is an important question, and more so to mills of light power than to those with plenty. It is to meet this question of varying speed from eye to skirt that curved dresses have been devised.

The dress that will suit 150 revolutions will not suit 175. One inch draft to the foot diameter is a common rule, but this must be deviated from according to the texture of the burr, the speed at which it must be run and the number of the furrows, particularly the number to the quarter. As regards the question of close or open stone influencing the draft, we may

say that if the stone is close there may be in some stones say 5 inches draft, and if open $5\frac{7}{10}$.

As a general rule the Germans say that without aspiration the draft should be three-fortieths of the stone diameter, and with aspiration one-sixteenth. In certain cases the short furrows may be allowed to run into the leaders before them. With close-grained stones this may be recommended for those who are not very skillful in handling them, although with correct dressing this necessity will not be felt.

The angle of intersection of straight furrows increases in proportion as this direction diverges from the centre of the stone, and *vice versa*, the angle must be small in proportion as the divergence is less.

In Fig. 229 we show a stone on which are drawn six different lines indicating the direction of the furrows : *a b* is the diameter of the stone, and *c d* the diameter of the dotted eye. The circle *e f* divides the radius of the stone into two different parts, and enables us to compare in the case of all six of the different kinds of leaders the angles of intersection formed by the leaders on the runner and those on the bed.

It is easy to see that furrows II and II′ intersect at angles entirely different from that formed by I and I′, and these again form a different angle

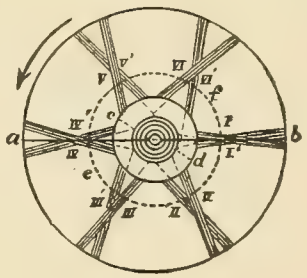

FIG. 229.

from III and III′, etc. The angle of intersection of II and II′ is greater than that of I and I′, and so on, the angle of intersection increasing with the increased size of the draft circle.

The question of draft runs very closely into that of furrow outline. In all quarter dresses having parallel secondary furrows, whether the leaders are straight, circular, or spiral, the draft of the short furrows is greater than that of the leaders ; and if it be a disadvantage to have greater crossing angle at the skirt than at the eye, the furrows that have the most draft will have the greatest crossing angle. If the short furrows are given the same draft as the leaders, they will have the same crossing angle at a given distance from the skirt, as the leaders have. There may be two or three different lengths of diverging furrows, all having the same draft at the skirt, though some of them may not reach more than half way in toward the eye. Dresses of this type will not be strictly "quarter dresses," although the leaders apparently divide them into so-called "quarters," or fields.

Ganzl & Wolff say that many millers suppose that the proper draft for the furrows is of real importance, while others think that of so little importance that they think that if the stone is open or porous there need not be any

furrows at all. There is upon record a test with a 5-foot stone running one hundred to one hundred and five turns, having a draft of four inches and sixteen quarters with three furrows to the quarter. This stone being run was then dressed down to the depth of the furrows and a new dress put in, with three inches draft, twelve quarters each having two furrows. Then, noting the product, the stone was redressed and given only ten leaders, with three inches draught. The second dress showed no difference in quantity of chop, and the difference in the last case was so little that it might be ascribed as well to faulty observation as to faulty distribution by the furrows.

Depth of Furrow.—Here again comes conflict. "The furrow should be shallow, because the runner should commence to work upon the grain of wheat the moment it starts up the incline of the furrow. If the furrow be deeper than the thickness of a grain of wheat, the grain will have traveled part of the way up before it commences to be acted upon by the runner. (This is supposing the case of an upper-runner, and the principle is the same for an under-runner.)

"If there is any difference between the furrows in the upper and lower stone, those in the upper should be the deeper. Those in the lower should not be deep enough to let a grain of wheat be covered.

"Middlings do not need deep furrows, but they should be deep enough to let the stones take the feed. Sometimes, with a high rate of speed, the driver and bail will prevent the middlings from feeding."

The author considers the rule that "the furrow depth should not be as great as the thickness of a grain of wheat," not based on any sound principle. Carried out to the next stage, and in the same proportion, furrows for middlings reduction would be of almost inappreciable depth. Less depth is needed where there is a "millstone exhaust."

"When furrows are not deep enough they will grind too slowly, are too apt to heat the flour, and the bran will not come out so clean; when too deep they will throw out small parts unground."

"Furrows, if they are given much draft, will not bear to be deep. Too much draft makes much coarse meal. Some advise making the furrows in the bed only half the depth of those in the runner, alleging that deep furrows in the bed are apt to throw out grain without proper grinding."

The Furrow Section.—"The section of the furrows depends very much upon whether you are grinding high or low, and require many or few middlings. For low grinding, a perfectly true taper is recommended from the first or back edge up to the feather, the depth being $\frac{3}{8}$ inch on the back up to $\frac{1}{16}$ or less on the feather for a new stone. When the stones are in good face the feather should not be deeper than the depth of a good heavy crack." Many think that the feather-edge should have no shoulder at all, and we are inclined to agree with them.

"Perhaps the reason that hollow or "gouge" furrows—that is, those with concave surface, have in some cases been found to grind cooler than flat furrows, is that they give more discharge, which was very likely needed for an excessive feed. In such a case it would be better to widen than to gouge the furrows."

The writer considers that the cutting work done by the back edge of the furrow is rather limited, and that the best section is that of a right-angled triange, having the right angle B in the bottom, the obtuse angle A at the front, and the acute angle C at the "feather-edge," or back, thus:

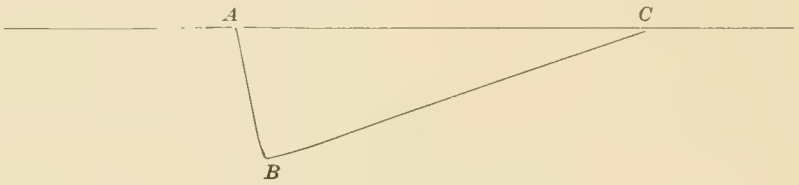

FIG. 230.—PROPER FURROW SECTION.

This gives freer action than where the obtuse angle A is at the bottom and the front edge AB is vertical, thus:

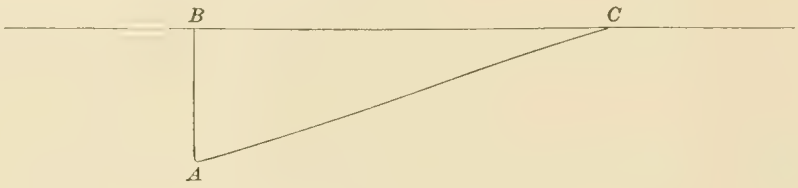

FIG. 231.—WRONG FURROW SECTION.

and the first section is easier made with a pick or an emery wheel.

"**Smoothness of Lands and Furrows.**—Smooth burr faces do better on hard wheat than on soft."

"There is no use in making the furrows like a bastard file, unless the object be to make flour that will bolt specky through a No. 16 cloth."

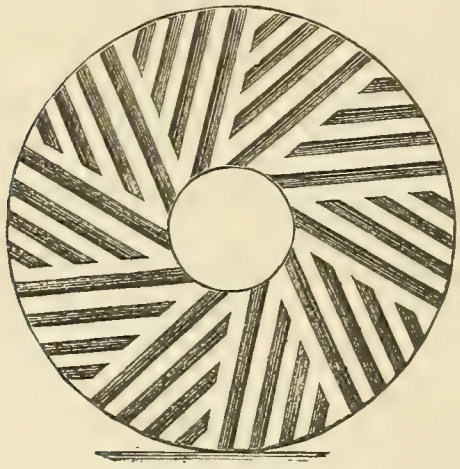

FIG. 232.—STRAIGHT QUARTER DRESS.

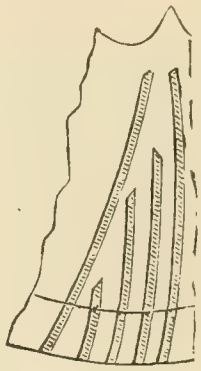

FIG. 233.—SICKLE QUARTER DRESS.

"The more even the porosity of the stones the more regular the furrows will be, and the more regular the ground product."

The smooth and the rough furrow advocates do battle on this head, without ever coming to much of a conclusion, or, rather, change of opinions. It seems, however, as though the smooth furrows cut the bran up less than rough ones, in wheat reduction; and many millers, while religiously adhering to "cracking" on the face, rub the furrows smooth with a corundum block.

Cracking the faces is now done finer and finer each year; the "diamond

dressers" having paved the way for this, and the emery and corundum wheel dressers following them up toward absolutely smooth land and furrow.

Quarter Dress.—In the cut, Fig. 232 is the old straight quarter dress, still much used in the South and in Great Britain. Fig. 233, a modification of the quarter dress, is the sickle.

Compromise Dress.—The "compromise" dress proceeds in a straight line across from the eye to within six inches of the skirt, and then turns a corner like the short furrows of the quarter-dress. We name this dress as an instance of "how not to do it." It combines the disadvantages of the sickle dress and those of the quarter, lacking the even regular draft of the sickle and the freedom of furrows of the quarter.

Pennsylvania and New Jersey Dress.—In Pennsylvania and New Jersey there is a very common dress, which may be adapted to any kind of dress without cutting away the old furrows. In all cases the upper stone, whether used as the runner or not, is cut in furrows with a deep square channel at the back, and feathered at the front; while the lower stone, whether used as the runner or not, is cut in shallow furrows of equal gauge

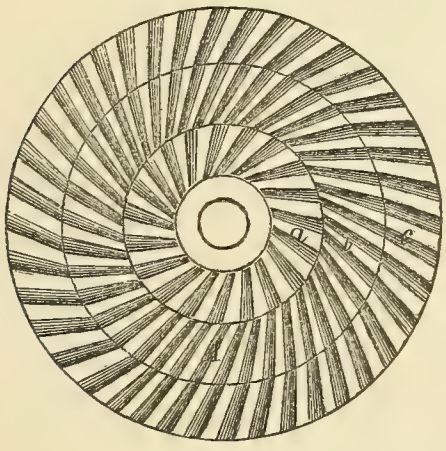

FIG. 234.—DICKSON DRESS (RUNNER).

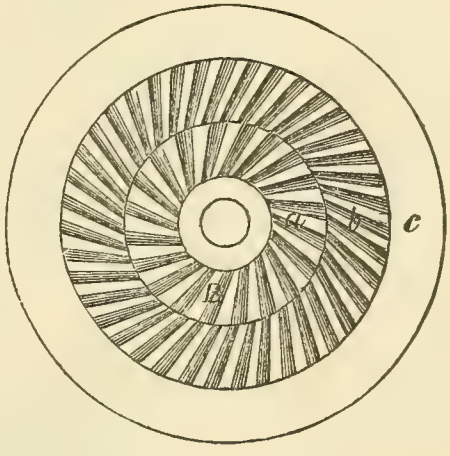

FIG. 235.—DICKSON DRESS (BED).

throughout. The furrows are broad and the lands are narrow. A 4-foot stone, with twelve leading furrows, will be $1\frac{1}{8}$ inches wide at the eye and $2\frac{1}{4}$ at the skirt, $\frac{1}{4}$ inch deep at the back, $\frac{1}{16}$ inch at the shoulder.

Old Style Equalizing Dress.—In nearly all cases the equalizing dress has 19 leaders and 19 short ones, the furrows being $1\frac{1}{4}$ inches wide, and $\frac{1}{4}$ inch deep at the eye of the stone, and $\frac{3}{16}$ at the skirt, with one inch draft to the foot for the leaders, and $1\frac{1}{4}$ to the foot for the short ones. With this dress the speed is about 200 revolutions.

New Style Equalizing Dress.—This has 20 to 21 leading furrows, $1\frac{3}{8}$ to $1\frac{1}{2}$ inches wide, draft according to the speed.

Combination Dress.—A "combination" dress used in our Western States has 14 sections, each of 3 furrows—the leader with $1\frac{1}{2}$ inch draft to the foot; second furrow connected with it at the eye; furrow depth, $\frac{1}{4}$ inch at the eye, $\frac{3}{16}$ at the skirt; feather-edge, except for 8 inches at the eye, where there is nearly $\frac{1}{12}$ inch cutting edge. At the eye the furrows cross each other

about at right angles; and half way to the skirt about 40°. The separation of bran and flour should take place at the skirt.

Dickson Dress.—The Dickson dress is shown in Figs. 234 and 235, the first being the runner and the second the bed. The cuts represent 4-foot stones with the grinding surfaces reduced to three feet. There should be about 20 furrows, *a*, in the stone, with about three inches draft from the centre of the eye. The second course of furrows, *b*, has double the number

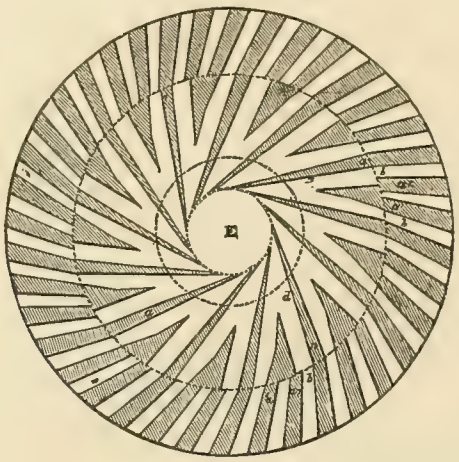

FIG. 236.—JONES DRESS.

of *a*, with at least five inches draft. More draft is given in the second course than in the first, because the grinding mass is more liable to clog when well pulverized than when only partially ground. The outside furrows, *c*, are not intended to grind, but merely to act as conveyors to deliver the ground mass. The bed-stone B, from course *b*, is dressed down below the grinding surfaces about $\frac{1}{4}$ inch.

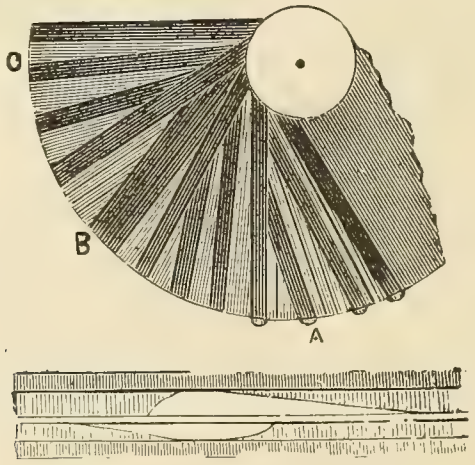

FIG. 237.

The Jones Dress.—The Jones dress, out of which so much money was made in England, is shown in Fig. 236. The stone has a central inclined concentric circumferential depression, *d*, around the eye *E*, and comprises one-fourth of the surface of the stone; *a*, a^1, a^2 are the grinding surfaces or lands, and *b* the furrows, and some of the lands terminate in an acute angle at the eye of the stone; this, as well as the intermediate lands a^1, a^2,

diminish in width from the curb inward, so as to allow the offal to be completely cleaned. This dress is claimed to enlarge the ingress of air and decrease the grinding surface, thus making a large quantity of cool middlings. The chief fault of this dress is that the intersection angle is very large at the eye, and decreases rapidly toward the skirt, giving a favorable angle for entrance, but an unfavorable angle for discharge. This fault, on the other hand, is overcome by the parallel dressing.

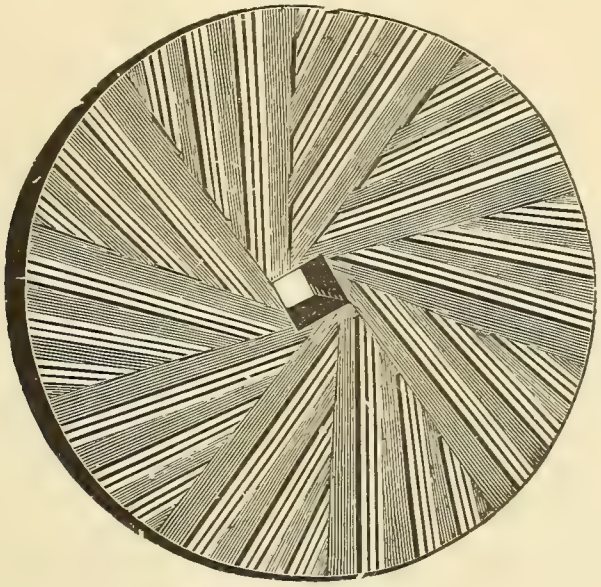

FIG. 238.—BOWMAN DRESS.

The dress shown in Fig. 237, is recommended by one of the correspondents of the *Millers' Journal.* The two quarters opposite A are for a 4-foot, close, new stock burr, with 12 quarters and 3 furrows to the quarter, with 3 inches draft from the feather-edge of the stone. In very open or old quarry stone, the same writer recognized two furrows to the quarter, like that opposite B. For three feet and under, the dress similar to

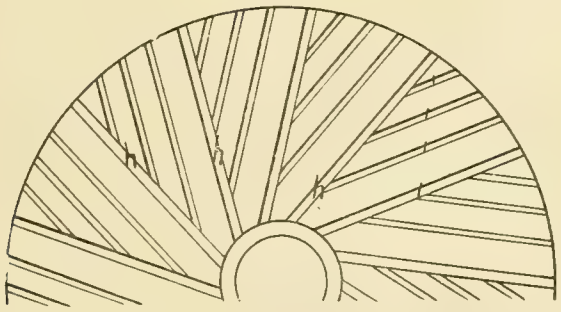

FIG. 239.—ARNDT DRESS—LOWER STONE OF UNDER-RUNNER FOR RYE.

that at C is preferred by the same writer, with the short furrows in front of the leading ones to enter them at the eye.

Bowman Dress.—The Bowman dress, shown in Fig. 238, is claimed to run very cool, and that it can be adapted to any style of dress without having to cut the stone away. In this dress the furrows in the lower stones are not so deep as those in the longer, and are made broad with narrow lands.

Arndt's Dress.—In Arndt's dress the upper-runner has not exactly the same dress as the upper. In Fig. 239 is shown the Arndt dress for a lower or runner for rye, and in Fig. 240 that for wheat. Fig. 241 shows the upper or stationary stone for either wheat or rye. The furrows for the lower stone or runner have less draft than those of the upper or stationary stone. By changing the number of quarters this inclination may be varied;

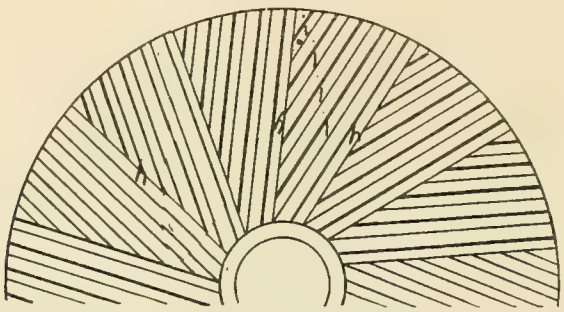

FIG. 240.—ARNDT DRESS—LOWER STONE OF UNDER-RUNNER FOR WHEAT.

the angle of the short furrows with the radius being less, with smaller furrows than with large. Arndt, for a stone with 88 to 92 turns, and for two breaks, gives 14 quarters to the bed-stone; gives for the third five breaks, 110 to 115 turns and 12 quarters; for the six inch to eight inch break, 115 to 120 turns and 10 quarters. It does not follow that there should be only 8 quarters and 90 to 100 turns for the ninth to the eleventh break,

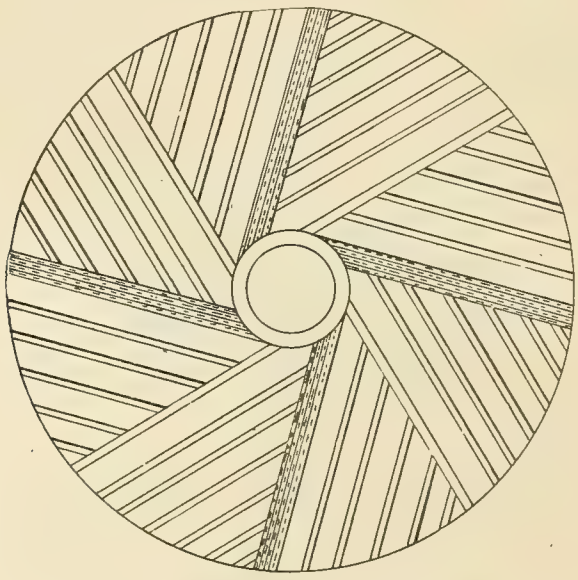

FIG. 241.—ARNDT DRESS—UPPER STONE OF UNDER-RUNNER.

because this would give six short furrows, and the shortest one would have far too much draft. In Arndt's dress the slope of the leaders is the same as in all ordinary dress, but the slope of the short furrows is reversed; that is, "the feather-edge upon the wrong side," according to the miller's usual custom. The short parallel furrows are narrower than the leaders. The harder the stone, the more parallel furrows there may be.

Ward's Millstone Formula.—By this method all the joints run in the back edges of the main furrows, thus preventing them from crossing the grinding surface of the lands. (See Figs. 242 and 243.)

One objection to the circle or sickle dress is that, having so many furrows crowded into the eye, these inner ends must be the smallest, thus affording much less space for the grain to pass through. Another objection is that the varying curve prevents the use of painted furrow patterns to keep the furrows of even size and shape and perfect finish. The furrows should be dressed up frequently, just as a saw should be frequently set as well as filed. One frequently urged objection to the circle dress is the apparent difficulty of laying out a curve ; but this is really an easy matter.

There may be said, in addition, against the circle dress, that it requires more time to keep the stone in proper order than the straight.

Hughes made experiments with the circular and the old-fashioned straight quarter-dress, with the result that the meal issuing from the stone was found to be warmer by ten to twenty degrees Fahrenheit in the circular dress stone.

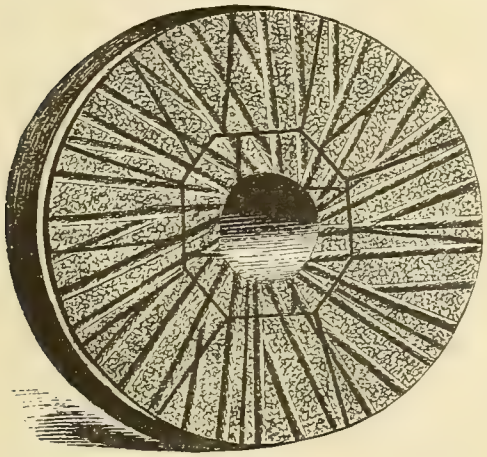

FIG. 242.--COMMON QUARTER DRESS—FURROWS CROSSING JOINTS.

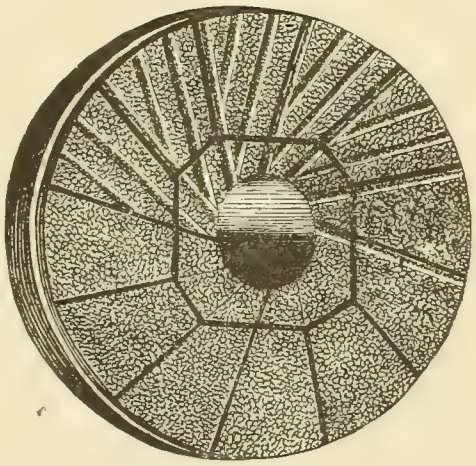

FIG. 243.—WARD'S DRESS—FURROWS ALONG JOINTS.

Dressing for Re-grinding.—On a 30-inch stone, the under stone being a runner, should have a bosom of $\frac{1}{4}$ inch, running out and becoming shallower six inches from the outer guy. Middlings do not require deep furrows ; they need a tolerably close burr. The feather-edge need not be prominent ; the burrs must be in perfect face, but not too sharp. The feed should be light.

The great problem under the new process is how to make the most middlings out of wheat. The Committee on Mill Machinery at the Millers' Convention at Cincinnati stated that it had heard of fifty per cent. of middlings claimed from one hundred furrows in a 4-foot stone, and the same result claimed with the three-quarter dress.

To make as much middlings as possible, the stones must be well dressed, perfectly balanced and the face perfectly true. There may be fourteen leading furrows, each with two short ones, forty-two in all, varying in width from one and three-quarters to two, or even two and a quarter, inches at the skirt.

Supposing we are using the same quality of burr in each case, we will note that old process milling requires wide lands and narrow furrows, whereas the new demands narrow lands and wide furrows, and also the face must be truer and smoother. For high grinding, about sixty-five per cent. of the entire surface should be in furrow. At least one-third of the diameter of the stone should be allowed for bosom. Perhaps it would be better yet if a perfectly graduated bosom was made from the eye to within two inches of the verge, making the depth from three to four thicknesses of paper down to nothing.

"Burrs 48 inches in diameter, running at 180 revolutions, and of medium old or open new stock, may be dressed about as follows: 14 sections each with three furrows $1\frac{1}{2}$ inches wide, $\frac{1}{4}$ inch deep at the eye, and a little shallower at the skirt. The furrows may be slightly concave. The leading furrows may have four inches drop to the feather-edge, and the other two five and a half inches."

Other Dresses.—For old process, a dress recommended by a Connecticut miller has 14 quarters, each with 3 furrows, 4 inches draft to the deep side or draft line, furrows $1\frac{3}{4}$ inches wide from eye to skirt, depth $\frac{1}{4}$ inch at the eye, $\frac{3}{4}$ inch at the skirt.

"For new process wheat grinding, a 42-inch stone may have 16-inch eye; 24 quarters, 2 furrows to quarter, furrows 1 inch wide, $\frac{3}{16}$ inch deep at skirt, $\frac{1}{4}$ inch at eye. In old process wheat grinding, a 42-inch stone may have 17 quarters, 2 furrows to the quarter, $1\frac{1}{4}$ inches wide at skirt, $1\frac{3}{8}$ inches at eye, $\frac{1}{8}$ inch deep at skirt, $\frac{3}{16}$ inch deep at eye. A 42-inch corn stone should have open hard blocks, 1 inch to foot draft, 17 quarters, 2 furrows to quarter, $1\frac{1}{2}$ inches wide straight through, $\frac{3}{16}$ inch deep at skirt, $\frac{5}{8}$ inch at eye. For middlings (old process), a 36-inch stone may have the same dress as for old process wheat grinding. The stones should be hard and comparatively close. Middlings may have a 30-inch stone, with 22 furrows, straight into the eye, and the same width and depth as for a wheat stone. Rye requires a middle dress between corn and wheat. Nearly every miller has his own views as to the proper dress for new process grinding." (Straub Mill Co.)

"Old process milling demanded three-quarters of the stone face to be lands and one-quarter furrows; new process requires the reverse, *i. e.*, one-quarter lands to three-quarters furrows. To reduce the lands surface, either widen the furrows or cut narrow ones (say $\frac{1}{2}$ inch wide) parallel with the main, starting at the skirt and running into the main."

For grinding middlings, the furrows should be kept about the same as for wheat, it being seldom necessary to crack the face. For corn, the burrs can hardly be kept too sharp.

"In flouring soft grades of wheat in California and in the South, a quick motion and line-cracked surface would do good work, where they would be ruinous for hard Northern wheat."

"The hard wheat of Northern Europe looks like birds' nails. It is exceedingly hard, and should be ground on a stone with shallow furrows."

"For grinding both hard and soft wheat, Pallett recommends thirteen or fourteen equal quarters, with three-fourths to each furrow, to be one and

three-eighth inches wide, having the second furrows cut into the leading one, but leaving the width of the stone constant at the inner end of the short furrow, giving the leader five inches draft, and making them a shade deeper at the eye."

"For corn grinding the furrows are better a little rounding, with double the depth of the feather-edge required for wheat."

One way to prevent heating is to dress without a bosom, then divide a 4-foot burr into sixteen divisions with straight furrows, draught one-half the diameter of the rock. Lay off the lands and furrows $\frac{1}{4}$ inch each, dressing smooth. Sink the furrow at the eye $\frac{1}{4}$ inch for corn, running out to $\frac{3}{16}$; for wheat $\frac{3}{16}$ at the eye running to $\frac{1}{8}$ at the skirt. If you crack, crack the lands in straight lines, square with the draft of cross lines, so as to make lines face in the runner and bed direct.

To prevent or lessen heating, give more bosom, or else make the furrows deeper and wider, making the leading furrows at the eye nearly $\frac{1}{2}$ inch deep, tapering gradually to the surface.

For middlings, Littlejohn thinks that the furrows should have a feather-edge and smooth surface, and the proportions of land and furrow about equal.

A Canadian miller recommends for a $3\frac{1}{2}$-foot stone, old process, 12 sections, 12 long and 24 short furrows; furrows $1\frac{1}{4}$ inches wide and of equal width throughout; short furrows not cut through to the long ones, but half an inch left between the end of the short and the side of the long one; depth, $\frac{3}{8}$ inch at the back, smooth dressed up to a feather-edge: draft, $4\frac{1}{4}$ inches from the feather-edge; speed, 190; 18 to 20 cracks per inch for seven inches from the skirt. From the edge of the cracked portion to the eye, as smooth as possible with little bosom.

CHAPTER XXV.

DRESSING THE BURRS.

First Dress—Picks—Tempering Mill Picks and Chisels—Position in Dressing—Paint Staff—Proof Staff—Staffing—Direction of Furrows—Draft Square—Furrow Strip—Redressing and Cracking—Cleaning Millstones—Mending Burr Faces—Pick Burr Dresser—Diamond Dressing—Benton Dresser—Hand Tools.

The First Dress—"Well begun is half done." Burr dressing may be divided into two portions, the original dressing, and the cracking and other treatment which keep them in good condition. It is not so easy for the manufacturer of the stone to dress it so as to get the best work out under the varying conditions prevailing among his customers, as for the customer, knowing his speed, material, and product and a hundred other elements which enter into this:—supposing, of course, that the miller has a sufficiently thorough knowledge of his art to enable him to choose and apply the best method for his particular case.

Let us commence by examining what is to be done in order to fit the stone for grinding. In buying burrs we may receive them dressed or undressed, that is, if we understand by dressing simply the rough pick-work which passes for such at many factories. The stone maker rarely does more than to divide the stone into a number of fields which he supplies with furrows. Makers are generally content when the grinding surfaces of the stones are perfectly even, although in many cases these factory-staffed faces neither allow the miller to redress them, or are themselves ready for grinding. Very often the factory dressing has to be ground off with sand or glass, or by letting the stones grind together. The first thing that the miller has to do to rectify the new stone is to begin with the faces before the stone is put in place to work. For this purpose he needs a superior staff, kept in perfect order, and a good supply of the best picks, sharp, well tempered, and of weight and size adapted for the work to be done. Picks can never be too sharp nor too carefully handled, otherwise cavities or depressions will be reproduced and the grinding faces never brought to a perfect level.

After the stone has been staffed and picked over ten to twelve times or more, and the factory face dressed over, it may be temporarily put into operation, preferably on rye. After two days' use in this capacity, it may be lifted once more. Then there is plenty of time for cracking, if cracking is resorted to, which is not recommended.

The quality of a dress depends upon the material of the stone, upon the condition and excellence of the staff and picks, as well as upon the degree of skill and practice and the perseverance of the dresser. When the stone has been put in good shape for grinding, it is determined whether the original

furrows are the right kind and direction, and whether they are to be allowed to remain so or be altered or dressed out.

Picks.—Picks should be from eight to twelve inches long, with a heft in the centre as much as can be kept and the ends slightly concaved, to give a good length and even diameter. They are made of $1\frac{1}{4}$-inch square bar. If no eyes are ordered, $1\frac{3}{8}$-inch square is used for 3-pound to $3\frac{1}{2}$-pound furrowing picks. For heavier picks, without eyes, $1\frac{1}{2}$-inch square is used. The aim should be to keep the picks as short as possible, so that they will strike solid and not spring.

The ordinary picks will weigh about as follows :

Width of Blade.	Cracking.	Furrowing.
$1\frac{1}{4}$ inches.	2 lbs.	$2\frac{1}{2}$ lbs.
$1\frac{1}{2}$ "	$2\frac{1}{2}$, 3, $3\frac{1}{2}$	3, $3\frac{1}{4}$, 4
2 "	$2\frac{3}{4}$	

Most pick makers advise the use of the grindstone only, for sharpening, and call particular attention to the desirability of using a quantity of water and low pressure. Many a good pick is spoiled by grinding on a dry stone and bearing on hard, by which means a pick can be spoiled very quickly. The miller is apt to say the pick is too soft and to send it back to be re-tempered. A pick can be spoiled so that it will not cut, by heavy rubbing on the stone that millers have on the husk when dressing. Packages and boxes containing picks sent to be repaired should not only be plainly marked with the address of the pick maker, but also have upon them the names of the parties to whom they are to be returned.

English steel is the most reliable for all kinds of picks. The furrow pick should not exceed ten inches in length by one and one-half inches in width, and the weight from three to four pounds. Cracking picks should be from eleven to twelve inches long and not more than two inches wide. The brighter the blue the better the temper, if the grain is close. The best mode of tempering is by careful heating in charcoal. The best solution, other things being considered, is the one that will give the hardness and toughness required at the lowest temperature.

A very fine preparation for making steel very hard is composed of wheat flour, salt and water, using, say, two teaspoonfuls of water, one-half teaspoonful of flour, and one of salt. Heat the steel to be hardened enough to coat it with the paste by immersing it in the composition, after which heat it to a cherry red and plunge it in cold soft water. If properly done, the steel will come out with a beautiful white surface. It is said that Stubbs' files are hardened in this way.

Picks may be divided into those with eyes, those without eyes, knife picks and patent picks. Those without eyes are far better than those with eyes, being more firmly held. For those without eyes there should be two handles, one short for furrowing, one long for lands. They are better too heavy than too light. Thin picks are disliked by reason of their tendency to tremble. Patent or compound picks have the body of wrought iron, with a little steel

plate at each end. They save pick handles, but are liable to tremble like the blades.

A well known maker of mill picks, in expressing his opinion as to the requisites of good picks, says: "In the manufacture of A1 mill picks, nothing but a close-grained cast steel should be used. This quality of the metal is told by the superior brightness and closeness of the steel when broken. The best shape for a furrowing pick is short, with the weight in the centre to avoid spring. The weight should be three and a quarter to four pounds. Cracking picks of the best shape should not exceed eleven inches long, with a natural bevel from the centre, so as to hold the handle better. To test the quality of a mill pick, it must be broken. A blue color shows hardness and temper. Grit, *i. e.*, cutting quality, is determined by a lighter blue and closeness of grain. Crystals denote 'burned' or overheated steel. Blacksmiths cannot temper picks, because as each piece of steel differs in the quantity of carbon it contains, it is only by experience that it can be determined to what degree of heat each piece must be subjected and when the tempering must be done. Three picks, using both ends with one grinding, should dress a 4-foot bed-stone. Many makers claim that a pick dressed by other parties

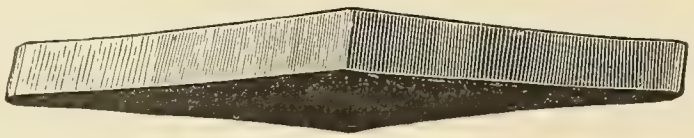

FIG. 244.—EYELESS PICK.

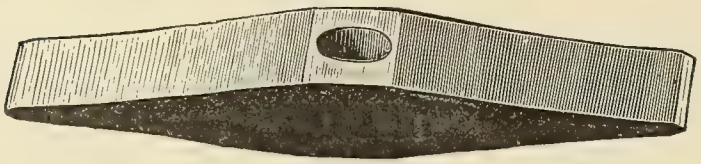

FIG. 245.—PICK WITH EYE.

and burned is ruined. This is not so. Unless the cracks are visible to the eye, any burned pick can be restored to its original cutting quality by a skillful steel worker. To prove this, the best picks are made from old ones which have been heated many times. Not more than one condemned pick in a hundred but what can be restored." Fig. 244 shows the pick for use in a patent head; Fig. 245 is supplied with an eye.

The picks made by John C. Higgins, 163 West Kinzie Street, Chicago, may be recommended.

Tempering Mill Picks and Chisels.—1. Heat the pick to a blood-red heat, and then hammer it till nearly cold; again heat it to a blood-red and quench as quickly as possible in 3 gallons of water, in which are dissolved 2 ounces of oil of vitriol, 2 ounces of soda, and ½ ounce of saltpetre; or, 2 ounces of sal-ammoniac, 2 ounces of spirits of nitre, 1 ounce oil of vitriol—the pick to remain in the liquid until it is cold. 2. One ounce of white arsenic, 1 ounce of spirits of salts, 1 ounce of sal-ammoniac, dissolved in 4 gallons of spring-water, and kept in a tube or iron phial for use. Heat the pick to a blood-red heat; then quench it in this mixture; draw it gently over the clean fire till the spittle flashes off it; then let it cool. 3. To 3 gallons of water add 3 ounces spirits of nitre, 3 ounces spirits of hartshorn, 3 ounces

of white vitriol, 3 ounces of sal-ammoniac, 3 ounces of alum, 6 ounces of salt, with a double handful of hoof parings; the steel should be heated a dark cherry red. Used to temper picks for cutting French burr-stones.

Another formula is as follows: 1. Take 2 gallons rain-water, 1 ounce of corrosive sublimate, 1 of sal-ammoniac, 1 of saltpetre, 1½ pints of rock salt. The picks should be heated to a cherry red and cooled in the bath. The salt gives hardness, and the other ingredients toughness to the steel; and they will not break if they are left without drawing the temper. 2. After working the steel carefully, prepare a bath of lead heated to the boiling point, which will be indicated by a slight agitation of the surface. In it

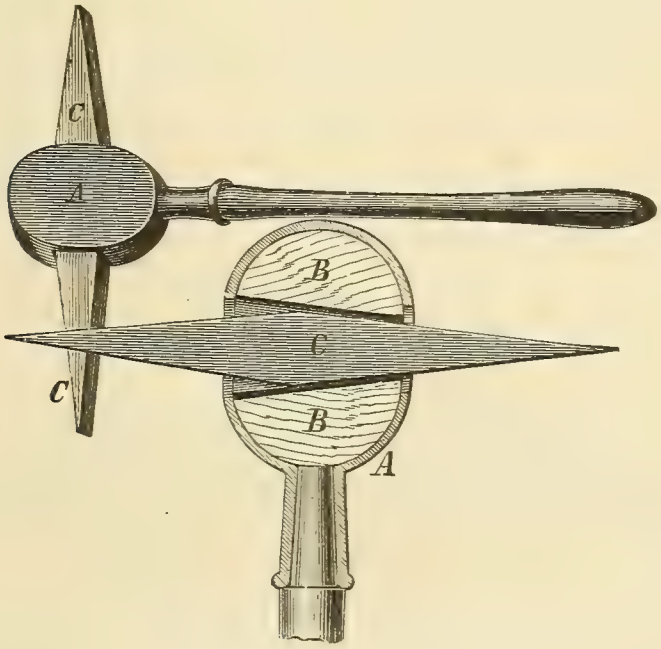

FIG. 246.—PICK IN PATENT HANDLE.

place the end of the pick to the depth of one and one-half inches until heated to the temperature of the lead, then plunge immediately in clear cold water. The temper will be just right if the bath is at the temperature required. The principal requisites in making mill picks are: First, get good steel. Second, work it at a low heat; most blacksmiths injure steel by overheating. Third, heat for tempering without direct exposure to the fire. The lead bath acts merely as a protection against the heat, which is almost always too great to temper well.

Position in Dressing.—Take a suitable cushion; place it upon the stone; lie down upon it, resting upon the left hip and elbow; take the pick firmly in the right hand near the end of the handle; clasp the handle loosely with the left hand near the pick, and, proceeding to work, dressing from you, crack the land the width of the pick. Do the work with the right hand, using the left to steady and guide the pick. Many millers have a flexible leather strap under the pick handle, as a guard to prevent the back of the hand from getting full of steel and stone from the picking.

Staffing.—Two surfaces working against each other tend to become parts of spheres. Either of them may become concave and the other convex with various degrees of curvature.

A plane surface, the line of separation between concavity and convexity, is the most difficult to hit—just as it is a great deal more difficult to make a perfect straight line than a perfect circle.

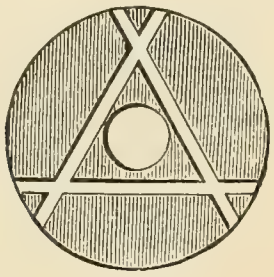

FIG. 247.

FIG. 247A.

Fig. 247 shows three beds, and Fig. 247A the same supplemented by three others. Not only must each bed be made true from end to end before beginning the next, but each must staff perfectly true on all beds that it crosses. To effect this a true paint staff must be used.

Fig. 248 shows the iron paint-staff, with level ; Fig. 249 a wooden proof-staff, and Fig. 250 its case.

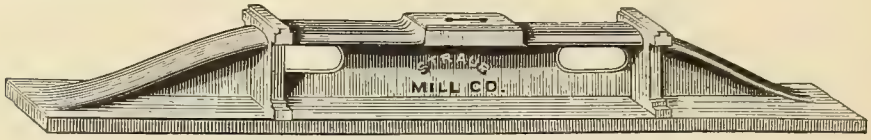

FIG. 248.—IRON PAINT-STAFF.

The Paint-Staff.—The paint-staff is to the miller what the surface plate is to the machinist. It is better bought than home-made. When of wood it should be composed of four or more strips of well-seasoned material—cherry is the best—trued up and glued together, with the fibres so lying as to prevent warping.

They can be made absolutely true only by making three at a time, testing the first with the second, and the second with the third, turning end for end.

FIG. 249.—WOODEN RED-STAFF.

They are proved from time to time by applying them to the proof-staff, which is made of cast iron, planed, filed, scraped, and which, to insure absolute accuracy, should be made and tested three at a time, in the same manner as the proof-staff. The ordinary planing machines, whether wood or iron, will not plane out of wind. The proof and paint staffs should be tested together by applying them and looking under them. Seeing no light places

under any portion of the edges, they should be turned end for end and tested in the same manner.

They should be further tested by laying four pieces of tissue-paper on the proof-staff and laying the paint-staff on them ; they should be painted equally at all points along the staffs. Unless a red-staff has its pores well filled it will be apt to deflect when paint is applied. The triangular staff made out of nine well-seasoned boards (that is, three on each wing) will keep in order longer than the ordinary straight staff. It should be remem-

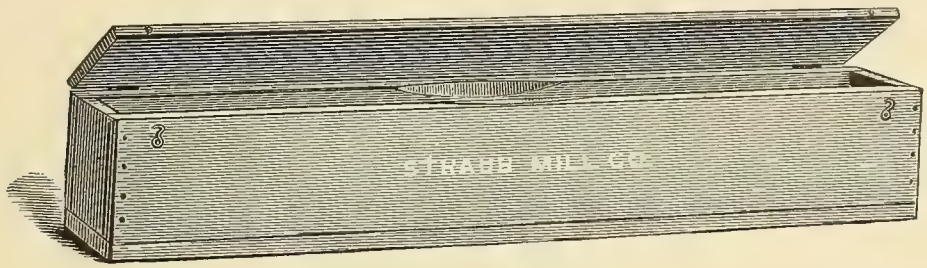

Fig. 250.—Case for Proof-Staff.

bered that, if the red-staff is out of true, the error will be doubled when the two stones, which are trued with it, are placed face together. The proof-staff should never be removed from its case, much less used as a level. "As the different blocks of a stone expand differently by the heat, the burr should be staffed when warm."

In how many mills do we find the most accurate appliances provided, and either carelessly or ignorantly used, or else positively abused, so as to have their value lessened. The paint-staff should never be used for any purpose

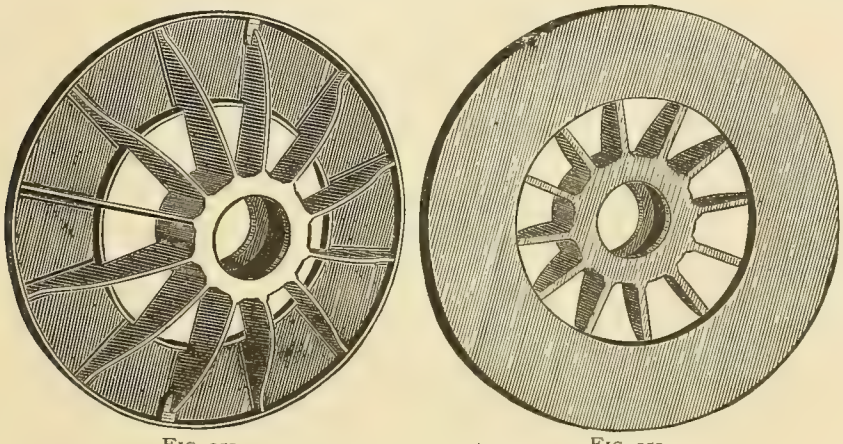

Fig. 251. Fig. 252.

Circular Iron Proof-Staff.

except staffing, and when used for staffing it should be used intelligently and with care, so that it can be depended upon.

In staffing, keep the staff away from the edge of the stone, as this is apt to be worn or broken away by bad balancing or other causes.

Figs. 251 and 252 show the circular iron proof-staff, which is self-explanatory.

The circular staff indicates at once a high place, but cannot mark a low place, as it takes a bearing only on that part that wants dressing. It needs

less skillful handling than a straight staff does. Perhaps better work than with either can be done with a triangular iron staff, which combines all the advantages of the straight staff and the circular, and it is as easily handled as the wooden staff, while doing as perfect work as the cumbrous circular staff.

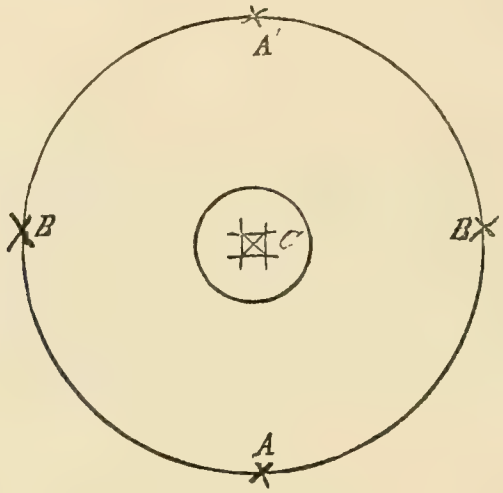

FIG. 253.

The first thing to be done in dressing a millstone is to make its face plane and ready for the furrows. To do this, lay the stone on its back, level its face as nearly true as possible; then, with the paint staff (which we describe at length under another head), mark the high spots, pick these off and rub the face of the stone with a sharp burr-block or a regular dresser.

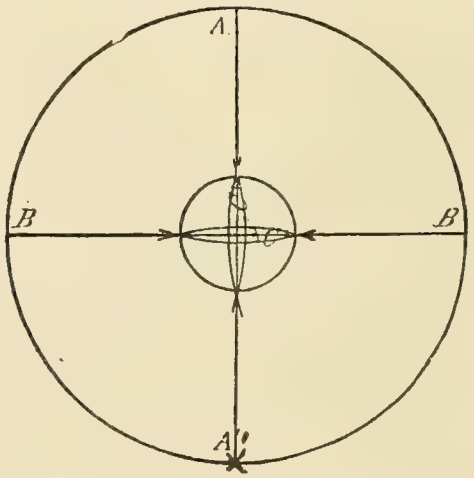

FIG. 254.

To take it "out of wind," fit into the eye a piece of board, into which drive a screw or a nail as a centre, and strike a circle on the face of the stone two inches from the verge.* Divide this into three equal parts by stepping off the radius on the circumference (which divides it into six parts), and

* To get the exact centre, divide the skirt into four quarters, by stepping, and draw two intersecting diameters through these from equidistant points. Or, take from equidistant points, A, A', B B (Figs. 253, 254); draw arcs, either lapping or nearing one another, and in the loops or squares formed by these arcs, draw diagonals, intersecting at C. (This is where there is no straight edge long enough to cross the stone, and no cord handy.)

taking every other point of division. Laying the staff on the inside of two of these points, draw a line clear across terminating at both ends in the verge, and in a similar way mark off three other lines on the face of the stone. Draw parallel lines about an inch farther from the first lines than the width of your staff. The strips between these parallel lines are called beds.

Painting the staff lightly, lay its face on one of the beds, and move it gently lengthwise. Pick off the higher points lightly and rub with a burr-block. Continue staffing and picking until the staff paints the whole length and the bed is nearly smooth; then work the other beds the same way, taking nothing off the point where they intersect one another. With the stone true in these three different directions, it is comparatively easy to make its whole surface true. When the face is true with the beds, wipe the staff and lay it on the face. If light can be seen between the staff and the stone, the face is

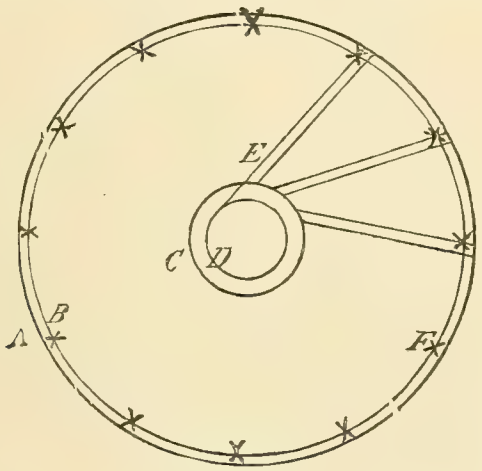

FIG. 255.

untrue. It must be staffed and worked until the stone points evenly all over and the staff does not rock. Of course small stones are easier taken out of wind than larger ones, because the same amount of surface has not to be picked off.

Divide the stone into the required number of quarters.* Make a point at each quarter; then, with a perfectly true furrow stick, the width the furrows are to be, lay off the leading furrows by laying it on the outside of the draft circle, having one end on the circle, the other end and same edge of the stick on the quarter points, marking them with a quill. If the stone is to be run "with the sun," the furrow stick must be laid upon the right-hand side of the draft circle and quarter points; if to run "against the sun," lay it the reverse. After the leaders are laid off, step them with the compass and correct them; then, taking the landstick, which is the width the lands are to be, determined by the number of short furrows between the leaders, continue around until all the furrows are laid off. Of course they must be of equal width, one with another.

For cutting, mark lightly with a light sharp pick the outline of the furrows, marking the feather-edge (that which is next the draft circle) only

*See FIG. 255.

lightly. Then with a heavy pick rough out the middle to nearly the desired depth, keeping the back nearly straight from the face of the stone, and nearly a quarter of an inch deep, tapering up the feather-edge. Then take a sharp pick and make them even and smooth their whole length. The bed-stone and the runner generally receive the same dress.

Direction of Furrows.—"The side of the draft circle on which the pattern is to be applied depends upon the way the stone runs.

"As a rule it may be stated that if the stone runs from right to left or against the sun, as indicated by the cut, then the leaders must be tangent with the draft circle on the left or toward the dresser.

"If it revolves from left to right or sunwise, as shown, then all of the leaders must form tangent toward the dresser from the draft circle.

"The furrows must always lie in front of the spindle. If the stone turns from right to left, then all the furrows must lie to the left in front of the

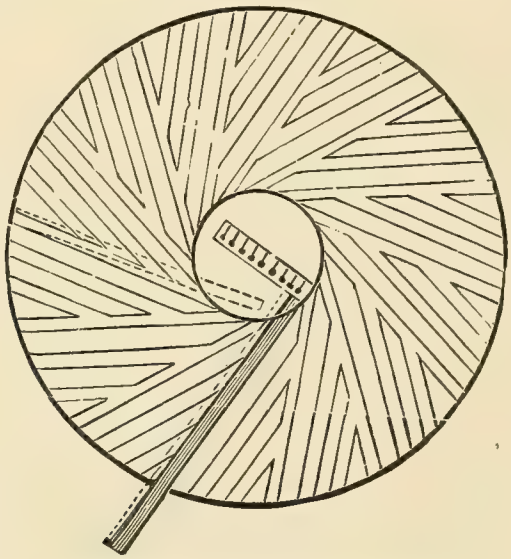

FIG. 256.—USING THE DRAFT SQUARE.

spindle; if the stone turns with the sun, then they must lie to the right in front of the spindle."

Draft Square.—The draft square may be applied, as shown, to the pin in the draft-board and measurements at the outer circle on the edge of the stone. Care must be taken to get the draft equal on all the furrows.

Furrow Strip.—To make all furrows precisely the same depth, cut a wooden strip four or five inches long and the proper section of the furrows. By this paint may be applied to the furrows to work them even. For flouring make the furrows as smooth as the face. Rough furrows make specky flour. Many a fault charged to the bolt belongs to the burr.

Redressing and Cracking.—At least every two or three months the furrow should be re-dressed. Every time the stone is taken up would be much better. In a busy mill the best stone requires to be cracked every three or four days. Cracking, however, is not now used for granulating. Cracking is cutting the face in parallel lines with the furrows, and *when well done* increases the capacity of the burrs and the quality of the flour. Where stones

have twenty-six or thirty cracks per square inch they do not require so much pressure. After taking up, the face should be rubbed all over with a piece of soft sandstone, then swept and staffed. If the stone is highest at the eye and breast*, clean off this face till the staff paints equally all over, then crack the rest of the surface. Should it be in good face when taken up, crack it all over with a sharp pick without breaking the face, then tallow the spindle neck. If the spindle is loose, tighten it, tram it, then put the stone down again."

"By cracking, not only part of the grinding surface is cut away, and the grain is too much chopped up. The stone is sharper after being cracked than before and will grind faster, but the flour will not be so good, being dark by reason of the particles of bran being cut up. When the burr begins to get smooth it begins to make better flour."

"Formerly thirty or forty cracks per inch were put in millstones to reduce and sharpen the grinding surface. Now this custom is superseded by the use of two-thirds furrow surface."

"With hard blocks the cracks should be deeper and closer than in softer ones."

"When the stones throw out small round pieces with parts of the meal ground too close this shows that they are out of face, and working entirely on some high part. In this case take them up; if the face prove true, the furrows may be too deep and rough, and should be filled with cement to the proper depth."

A better way than to sharpen all the furrows at once is to freshen up four or more furrows at equal distances apart on the bed, when the stone is taken up to dress; then next time that the stone is up freshen four furrows on the runner, and so on. By this means the action of the stone will be kept more even than if all the furrows are brought to life at one time, and all allowed to get in bad condition at once.

Cleaning Millstones.—Vinegar or apple cider is often used for cleaning the face. Some use a piece of soft sandstone. A twig broom does well to loosen the caked material, and may be followed by a brush. Some use a hand-bellows to clean out the larger furrows. A solution of borax is sometimes used to open the pores and remove the glaze in stones, and muriatic acid and water may be used. Many millers use a piece of leather ten inches wide and two feet long, known as a "strap." With this the stones are slapped till all the dust is taken out of the pores.

Many dispense with the washing of the stone; others wash without knowing why they do it. One good reason for washing is that there are many substances, such as garlic, that need to be removed in just this way.

Another reason is that, when clean, the stones are more readily staffed and dressed. Some think that the stone is softened by washing, but this is impossible. The stones should be washed every time they are raised. A composition for cleaning burr-stones is one gallon hot water, two ounces borax, three balls of sal prunella (each the size of a hazel nut) and one-quarter pound of washing soda.

* The breast means the bosom.

"When taking up the stones wet them with warm water, and rub them with a scrubbing-brush and a little soap and water, to remove the glaze. With a large sponge soak the water off the stone. The burrs which have been grinding corn will be apt to have a face saturated with the oil of corn, making them greasy. If they have been cracked often for wheat these cracks will be closed, and they will not clean the offal."

Mending Burr Faces.—This should not be postponed. If a furrow crosses a seam, and some of the corners of the seam spall off, the cavities should be mended or filled by a cement of four ounce weight of No. 4 emery, four ounces of gypsum and four ounces of alum, the alum being heated until melted, the plaster being mixed with water to the consistency of cream, then all heated together and the emery stirred in well. The cavities must be washed with a solution of sal ammoniac before putting in the

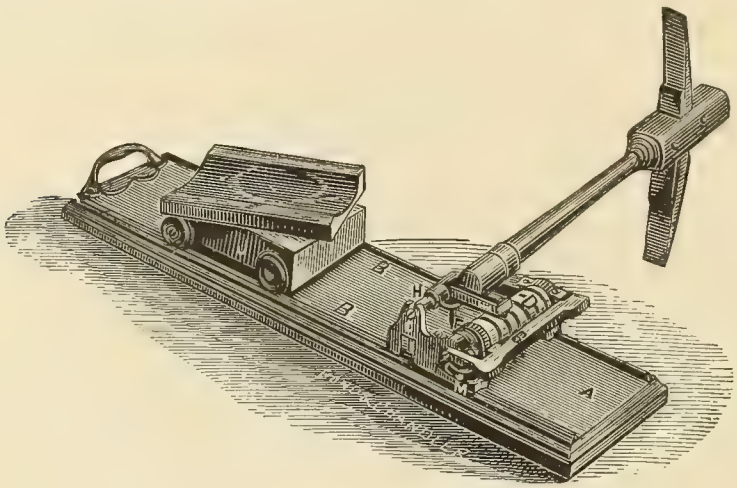

FIG. 257.—PICK BURR DRESSER.

cement. The oxychloride of magnesium, made by adding a solution of chloride of magnesium to the oxide of magnesium obtained by calcining magnesite, is the best cement for millstones. When used in repairing burr-stones, the cavities are wetted with the solution of chloride of magnesium, and the powdered oxide, mixed with powdered burr-stone, is rammed in.

Pick Burr Dresser.—Fig. 257 shows a device intended to make the cracks by a pick more uniform in depth and spacing than can be done by the hand alone. The arm rests on a swivel block on the carriage J, which runs along the bed-plate A, resting on the burr face. A suitable adjustable feed motion advances the pick crosswise of the bed-plate at each blow.

Diamond Dressing.—There are two kinds of diamonds used—"carbons" and "boarts." Carbons are dull and black in color, irregular in shape, and have sharp, rough edges. Boarts are brilliants that for their imperfections are unfit for polishing. They are generally round and without the sharp angles of the carbon, hence not so good for millstone dressing. The best carbons come from Brazil; others from South Africa and Siberia. Diamond dressing is specially adapted for stones to grind middlings, which feed irregularly and have no bran between the faces of the stones, and hence tend to harden their surface and glaze them. S. Dessau, 4 Maiden lane, New York,

imports these black diamonds specially for milling and other mechanical purposes. Caution and experience are necessary in buying carbons, as they vary in density and hardness.

Diamond dressing machines save the time of the miller and of the millstone. In putting a new diamond point in the machine, care must be taken to get its cutting edge parallel with the course of the tool, otherwise it would make a broad cut and ruin the diamond. The diamond dressing machine will dress four to five pair of burrs a day, thereby saving four to five days; if the mill expenses were twelve dollars a day, the saving would be sixty dollars for this time.

The Benton Dresser.*—The diamond dresser in P. P. Benton's patent, No. 222,443, dated December 9, 1879, has a staff-bed, bearing a frame, which forms the ways upon which the carriage works. This frame is fastened at one end by the bolt permitting it to be inclined to the right for furrowing. At the other end of the frame there is a bolt which passes through an eccentric in the bed, the working of which raises and allows the

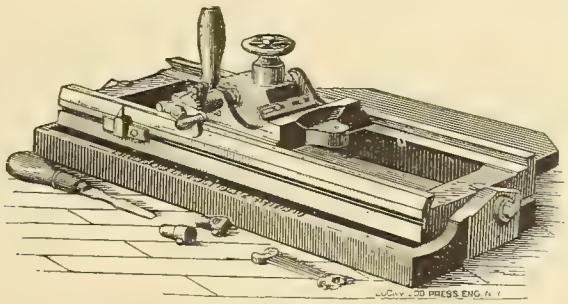

FIG. 258.

frame to cut deeper at the eye, and to adjust the cut of the diamond to the staffing (Fig. 258).

In the Uhlinger patent, No. 182,358, July 26, 1876, the upper surface of the end cross piece of the base-plate rise to a common central elevation, upon the top of which are studs passing through slots in the cross-bars of the bed-plate proper, dividing the bed-plate centrally lengthwise. By grooved slotted standards and screws the bed-plate is held rigidly at any desired angle. To hold it perfectly level, there are wedge pieces which may be turned in. To furrow, the wedge pieces are turned out, the desired angle given to the bed-plate and the screws tightened.

In the McFeely patent, 188,022, March 6, 1877, the carriage is upon a separate frame having carriage guides. The carriage bed can be tilted to any angle corresponding to the furrow, and tightened by thumb-nuts. The carriage will travel crosswise up and down the incline of its bed, according as it is set.

In the reissue patent of L. Moore, 7,744, June 19, 1877, there is used in connection with the guide-plate a bed-plate, on which the guide-plate is made adjustable by means of set screws and packing pieces.

* Made by the Benton Diamond Burr Dresser Company, La Crosse, Wisconsin. Patented September 26, 1876; March 6, 1877; June 19, 1877; April 2, 1878; April 29, 1879; December 9, 1879. The European agents are William R. Dell & Son, 26 Mark lane, London, E.C., England. The company manufactures three kinds of machines: "A," "B" and "C."

Emery Wheel Dressers.—These are not in very general use. J. W. Hoffman, of Three Rivers, Mich., certifies that an emery-wheel machine saves from one-half to two-thirds the labor and time of furrow dressing with the pick. The machine should be carefully used in order that it may not burn or glaze the millstones. W. R. Cooper, Sag Harbor, N. Y., says than an emery wheel dresser has paid its cost in dressing the stones in his

FIG. 259.—HAND BLOCK RUBBER.

new mill. Walker & Marple, Three Rivers, Mich., says that with an emery wheel machine they furrowed four run of 4-foot stones and one run of 4½-foot stones in seven and a half days.

Hand Tool.—This is for truing the face and furrows of burrs, cutting down high spots, removing glaze, and restoring the stone to its original grit.

CHAPTER XXVI.

OPERATION OF THE BURRS.

Operation of Grinding — Diameter of Burrs — Table of Rim Speeds — Speed of Grinding — Dress and Quality of Stone — Trouble in Grinding — Quality of Burr Flour.

Operation of Grinding.—"The grain falling into the eye is swept around between the two irons until caught between the stones. At first it is only cracked. As it approaches the skirt it is reduced finer and finer. The ratio of increase of velocity cannot be calculated, but the revolving velocity of the grain at any point must be somewhere between nothing (that of the bed-stone) and the speed of the runner. Its outward progress is modified by these two conditions. Its course is complicated and undefinable. If too long confined, the flour will be hot and "killed," and will not rise and make bread. If it passes through too rapidly it is wastefully ground."

It is assumed that the material is drawn in between the burrs, partly by so-called "centrifugal" action (if in an upper-runner mill), and partly by friction. Both these causes tend to carry it out toward the skirt, and are aided (very slightly) by the crossing of the furrows, and more by the air current, if a "millstone exhaust" is used. With certain conditions of furrows there may be some nipping and shearing of the berries; but probably the granulation is based more on the cutting action of the large pores of the discs (where these exist) and on a crushing or mashing apart between two passing inclined planes. With plenty of furrow surface there is probably more cutting or mashing apart. Between smooth lands it is likely that tearing apart by friction enters largely into the work; and with roughly cracked lands, grinding is liable to be merely a continued abrasion.

There is a wide difference of opinion on the above subjects, and an almost equally wide variance of practice. A millstone is proverbially a difficult thing to see through, and what takes place under it is largely a matter for conjecture.

There was a time when, taking four millers, two of whom had similar, and the other two widely dissimilar conditions, the first two would have widely different theories and practices, and the second two would think and work almost identically. In these days there is rather more thinking and comparison and a resulting improvement in granulation, from a commercial as well as a technical point of view. Wheat splitting is done by a dress that nips and cracks the berry; flouring at one operation, by fast-running stones close together and having one-third their area in furrows; "middlings making," by slower stones farther apart and furrowed over two-thirds their surface; middlings flouring, by shallow furrows; and bran dressing, by stones having less furrow surface than for granulating.*

The variable elements in granulation and grinding by burrs, are diameter, speed, quality of stone, and dress.

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* See Chapter XXIV. on Various Millstone Dresses; also, Chapter XXXI. on Systems or Processes.

Diameter of Burrs.—When we consider the question of the diameter of the stones, we must remember, that *all* conditions cannot be equal, when we have a comparison to make. If stones of different diameters have the same rotation speed, they will have different rim-speeds; if their diameters are as three to two, their gross areas will be as nine to four.

A five-foot burr has 15.7 feet periphery, and 19.635 square feet area, exclusive of the eye. A three-foot stone has 9.424 feet circumference, and 7.068 square feet area. Deducting from the first, 18 inches for eye; and from the second, 12 inches eye, we have left 17.868 square feet for the large stone, and 6.2826 square feet for the small one.

At 200 revolutions the three-foot stone would have a rim-speed of 1884 feet per minute. To get the same rim-speed, the five-foot stone would need to run only $\frac{3}{5}$ of 200 = 120 turns. (See table of rim-speeds, etc.) With the same rim-speeds it will be seen that the grinding areas per minute are widely different. 17.868 × 120 = 2144.16 square feet per minute, that will pass a given radius; 6.2826 × 200 = 1256.52 square feet in the same time.

Hence, equalizing the rim-speeds, will not equalize the areas passing.

Between a few large stones and more small ones of the same actual capacity, as proved by actual work done at such speeds for each, as will best suit all the conditions (or as many of them as can be suited). The author, leaves the reader to exercise judgment—merely saying that large stones are heavier; hence, cause more springing and wear; the time lost in dressing one run at a time is proportionately greater; it is less convenient, and more expensive to have a set of spare stones, and to change the dress or speed for a particular purpose.

The following table gives the circumferences of millstones in feet and in inches; their areas in square inches; and their rim-speed in feet per minute at various rates of rotation. It will be noticed that the circumferences and areas are more fully filled out than the rim-speeds:

TABLE OF RIM-SPEEDS IN FEET PER MINUTE.

Diameter—inch.	Circumference—inches.	Area—square inches.	Diameter—feet.	Circumference—feet.	Revolutions per Minute.					
					100	120	140	160	180	200
18	56.55	254.47	1.5	4.71	471	565	660	754	848	942
20	62.83	314.6	1.667	5.24	..	..	..	..	..	..
22	69 12	380.18	1.833	5.76	..	..	..	..	..	..
24	75.40	452.39	2.	6.28	628	754	910	1005	1131	1256
26	81.68	530.93	2.167	6.81	..	..	..	..	..	..
28	87.96	615.75	2.333	7.33	..	..	..	..	..	..
30	94.25	706.86	2.5	7.85	785	943	1100	1257	1414	1570
32	100.53	804.25	2.667	8.37	..	..	..	..	..	..
34	106.81	907.92	2.833	8.90	..	..	..	..	..	..
36	113.09	1017.9	3.	9.42	..	1131	1219	1508	1696	1884
38	119.38	1134.1	3.167	9.96	..	..	..	..	..	..
40	125.66	1256.6	3.333	10.47	..	..	..	..	..	..
42	131.95	1385.4	3.5	11.	942	1219	1539	1760	1879	2199
44	138.23	1520.5	3.607	11.52	..	..	..	..	..	..
48	150.80	1809.6	4.	12.57	1257	1505	1759	2011	2264	2513
54	169.65	2290.2	4.5	14.14	1414	1696	2262	..	..	..
60	188.50	2827.4	5	15.71	1571	1885	2042	..	..	..

Speed of Grinding.—Slow grinding makes more middlings than fast. A close stone should not be clogged with grain under any circumstances. or it will grind warm. In fact, no stone should be allowed to be clogged.

Perhaps the greatest evil in milling is fast grinding. Flour once killed by over-heating can never be restored by any means.

There is more flour ruined by being under the stone too long than by passing under it too quickly.

"A four-foot stone for custom grinding should run from 150 to 160 on wheat, and not over 175 or 180 on corn. For merchant work 140 to 150."

There seems to be a tendency to fast grinding, which is doing harm to most of the systems now in use.

The usual problem being to get all the middlings possible, the miller should choose such conditions as will, other things being equal, make the yield of middlings high and the quality round and sharp. And the speed must not be left unconsidered.

Slow grinding generally makes more and sharper middlings than faster grinding does.

Dress and Quality of Stone.—These questions have been more fully considered in the proper chapters, to which the reader is referred.

Troubles in Grinding—Are many; the reasons more numerous. In the matter of warm grinding, there are many causes of this difficulty, one of which is clogging. The miller must not expect too much of a stone. In the South there is liability to fast grinding, which destroys the little gluten the Southern wheat has got.

Clogging is another evil that the miller has to contend against. If the spots are too small or of too slight pitch, or so arranged that in clogging the matter cannot be got out or jarred loose, there will always be more or less trouble, and this trouble might have been avoided in the beginning by proper attention to size, pitch, etc.

So long as the stone grinds right, it makes no difference whether it rises or falls or not. It is the expansion of the spindle that raises the runner at first, but if the heat reaches the burr and expands that also, the stone is somewhat lowered. The expansion of the stone itself tends to bring the burrs together. The stone may be lifted by the expansion of the burr, if this latter be too tight or gets dry.

The mill spindle should be kept well oiled, because not only does the increased friction necessitate a greater amount of power to drive the stones, but the spindle itself becomes abraded, and may heat so as to stick in the step. This often occurs.

Some men have no end of trouble with their purification, and others none at all, the machine being just the same. The cause of this is the condition of the middlings. If you have flat irregular middlings of all sizes, you must expect to have trouble in their purification, especially if your mill be too small to make it economical to grade. Maxim: Have round granular middlings. Then the question comes up, How can you have them in this condition? And the answer to that question is, By having the stones in good face, well balanced, the spindle trammed, the furrows in proper condition and

enough of them. The wheat must be thoroughly cleaned and free from foreign substances. The burrs must not run too fast. Now, flat irregular middlings are caused by the opposite of any one of these conditions, except it may be grain cleaning, and even that has an influence on the middlings.

There are mills where the purifier has not yet entered, and of course the proprietors are apt to "get left" in the matter of quantity and quality, especially the latter, and he must do his best to get good results without a purifier.

In order to get middlings in the proper condition without grading, and without too much dusting, etc., the stones must be adapted to the work to be done. They require the greatest care, not only in getting them ready to run on middlings, but in keeping them fit to do this daily work.

The middlings stones should be the sharpest and keenest in the mill.

Soft wheat should, when practicable, be ground in fine clear weather In the spring, wheat is harder to grind than at any other time, because a new fermentation takes place. It is not a fermentation; it is a natural swelling of the germ in the germinating season.

The Quality of Burr Flour—Varies as a matter of course. Although color ought to be one of the last things to be considered the prime point in flour, yet, as things are now, it is a desideratum, and we must make flour to suit the market, as we cannot make the market suit the flour.

Sometimes we see two widely differing lots of flour made from the same grade and quantity of wheat and in two mills built almost exactly alike. But there are many reasons for this difference.

The difference in color in flour made in different mills may be owing to the difference in the dress, in the grit of the stone, or in the speed of the burr. It may be poorly bolted in one and well in the other.

"Flour made by stones has a darker shade than that made by rollers, even if the same clean middlings are used in both operations. Differentially-speeded rollers give yellower flour than equally-speeded rollers, chilled iron more yellowish than porcelain, and unventilated burrs than ventilated. This cannot be attributed to heating during grinding, as yellow flour, if pounded in an agate mortar, becomes white."

One trouble that the miller often has with the farmer is that the latter often brings foul wheat and demands the highest yield.

Bread made from granular flour is said to keep moist much longer than that which is from less granular.

CHAPTER XXVII.

COOLING THE CHOP.

Millstone Ventilation—High-Pressure Aspiration.

Millstone Ventilation.—Rapid feed or too great pressure causes heating of the chop. Even with the best dress and the greatest care there will always be some heating and wasting, the waste and flour dust together form a paste on the sides of the hoop in the elevator pipes and conveyor screws and bolting machines, rotting the wood and clogging the silk, besides wasting flour. To prevent this a current of air is used, drawn from the circumference of the burrs. As long as the burrs remain cool they remain sharp, and the longer they are sharp the longer they will produce a sharp, white flour. Cool grinding develops the quality of the flour. The cooler the burrs the more they grind. The cooler and drier the flour the more the bolts can handle.

The injury from the heating of chop grows proportionately with the rate of feed and pressure, the present tendency being to rapid work. Heating is more common than usual. While it may be reduced by careful dressing of the burrs, yet even with the best dress this will not do away with the evil of sweat, which in damp or cold weather settles on the sides of the millstone hoop, in the elevator pipes, conveyors and bolts, forming with the flour dust a paste that soils the cloth, sours and infects the air, rots the wood, clogs the silks and passages of the machines, and wastes flour dust.

Attempts have been made to blow air from the millstone eye, between the two stones, but this gave trouble by filling the mill with flour dust. At present suction is substituted for blast, the air being drawn at the skirt. As ordinarily but imperfectly applied the construction is about as follows: a short leather hose hangs from the top of the hoop and either slides on the surface of the upper stone, or fits loosely into the mill ring fastened to the stone. From the top of the hoop there is a wooden or sheet-metal pipe to the main exhaust pipe which leads into the dust room. The demerits of the system are: the leather hose soon wears out from friction with the stone or ring; a strong current of air cannot be applied by reason of imperfect fittings; too great loss of flour dust; and sweating, while it is barely prevented in the hoppers and conveyors, is not obviated in the dust room and dust pipes. In the last we find the walls covered with paste. Furthermore, there is great danger of explosion by reason of the exhaust pipes and dust rooms being constantly filled with an explosive mixture of fine dust and air, liable to be ignited by a piece of iron accidentally entering the burrs. Mills have frequently been wrecked from this cause.

Bovill, in England, lessened the loss of flour dust by making a cloth partition in the dust room; and Perigault saved considerable flour by leading the dusty current through a room having several partitions, which, rapidly changing the direction of the current, causes a deposit of the flour. To lessen the formation of paste, double walls were provided for the dust pipes and dust rooms, and even steam-heating pipes supplied.

High-Pressure Aspiration.—The Behrns & Brehmer high-pressure aspiration device, illustrated herewith, is intended to afford perfect cooling, ventilation and freedom from dust. The following description will be readily un-

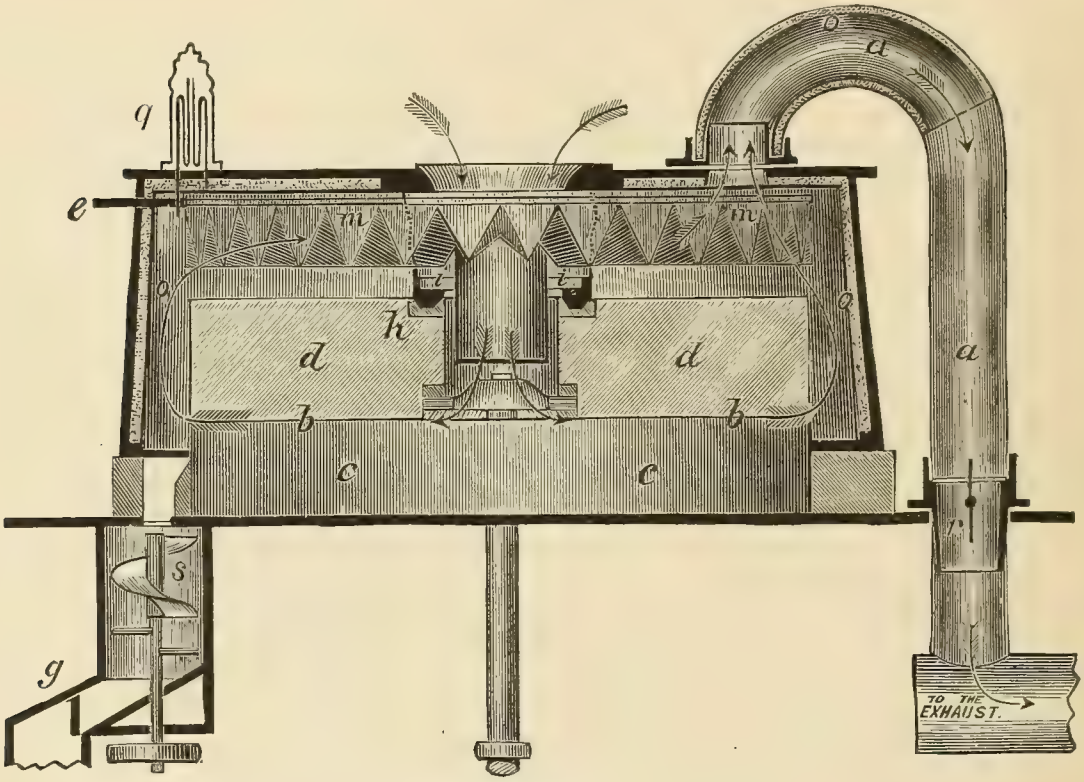

FIG. 260.—BEHRNS-BREHMER EXHAUST.

derstood, reference being made to Fig. 260. In this instance, *cc* and *dd* represent the stones, the upper one being the runner, and *bb* the grinding surfaces. A fan exhausts the air through the pipe, *a*, from the millstone hoop, while fresh air re-enters through the eye of the millstone and passes between the grinding surfaces, as shown by the direction of the arrows in the engraving. In order to make the supply current of fresh air as strong as possible, the hoop is made air-tight, and suitable connections and fittings are employed for the inlet as well as the openings of the chop discharge. For the inlet this is accomplished by means of two V-shaped cast-iron rings, well fitted together. The lower ring, *h*, is fastened to the running stone, while the upper one, *i*, is riveted to a leather cylinder suspended from the top of the hoop. A small chain fastened to the side of the upper ring prevents it from turning. The discharge opening prevents likewise the entrance of air at that point by means of the flap valve, *g*, as well as by the chop itself, which is

pressed by the revolving screw, *s*, downward through the inclined part of the discharge pipe, and forms there an air-tight mass while the valve *g* is held open. By this means it becomes possible to draw a strong current of air through the grinding surfaces of the burrs, which is designed to keep the meal or chop perfectly cool during the process of grinding. It will be readily seen that such a strong air-current must necessarily carry with it a considerable quantity of flour dust, which would find its way through the exhaust fan unless provided against. In order to retain this flour dust within the hoop, the following device is applied: over a light iron framework, *m*, is stretched and laced up in zigzag shape, a cloth of long-haired flannel. The frame, if suspended by three hooks under the top of the curb, and the flannel

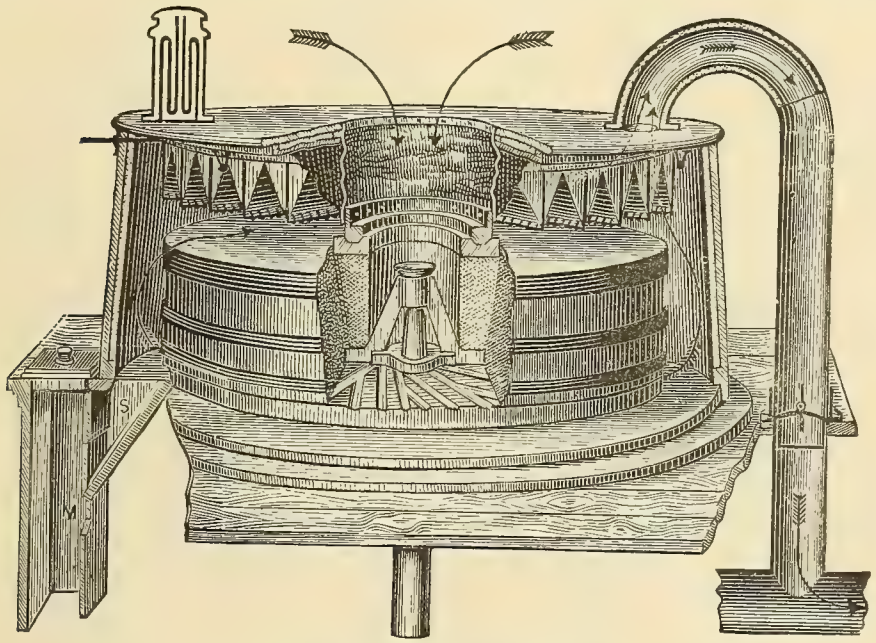

FIG. 261.—BEHRNS-BREHMER EXHAUST.

is tacked loosely, but dust-tight, against the top, at the outer and inner diameters of the frame. The nature and texture of the cloth are such, that although it detains every particle of flour dust, it allows all the warm air and the vapor generated by the dampness of the grain to pass through freely. The dust, therefore, gathers under the cloth, from which it is loosened and drops into the chop by slightly tapping the pin, *l*, at occasional intervals, the suction valve, *r*, being closed for a moment to allow the dust to drop off freely. The condensation of the vapor within the hoop, as well as the choking of the dust-catcher, is prevented by lining the entire hoop with a non-conductor, *o*, composed of felt, and which is covered over with galvanized sheet-iron. The upper curved part of the exhaust pipe, *a*, is also protected in the same manner, so that the condensation can commence only when its effect will be harmless. The vapor, on being condensed into water, will pass with the air-current through the exhaust fan and thence to the open air. A double vacuum gauge, *q*, is placed on the top of the curb or hoop, and shows the rarefaction of the air both inside and outside the dust-catcher. The time

when the dust should be taken off is thus indicated. The intensity of the current of air, which may be regulated by the check valve, *r*, is also accurately determined by the vacuum gauge *q*. The advantages which are obtained by this invention are numerous and important. The old method of ventilation permitted only a moderate current of air to be passed between the stones, on account of the great loss of flour dust incurred by a strong current; but with the use of this aspiration, as strong a current of air as could possibly be desired for cool grinding is easily produced, and is not attended with the loss of a particle of flour dust. It is also evident that by its use the capacity of a mill can be considerably increased. In preventing the condensation of vapor, this apparatus causes the formation of paste to cease, and no trouble from this source with conveyors, elevators and bolting cloth

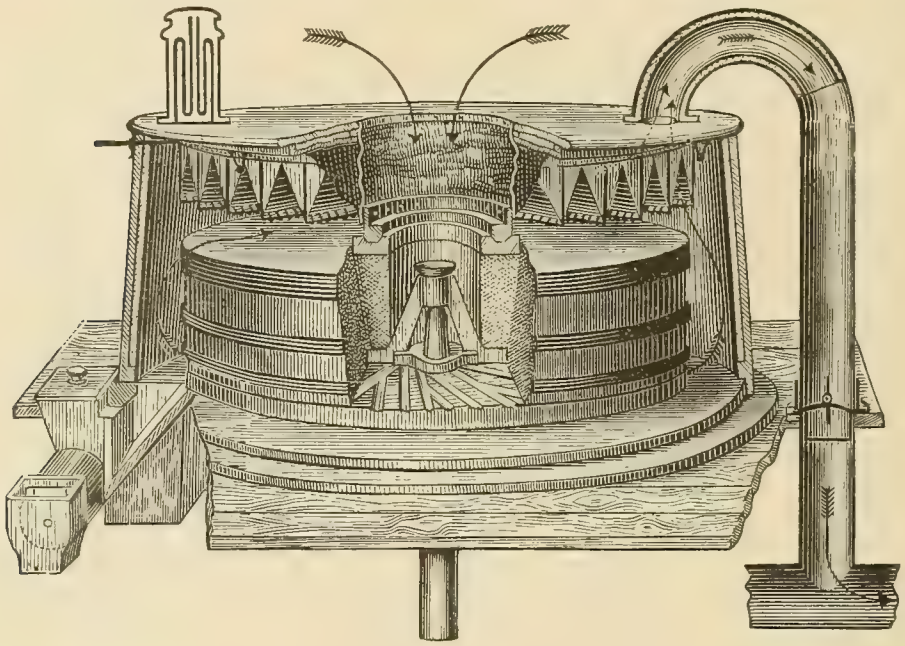

FIG. 262.—BEHRNS-BREHMER EXHAUST.

is experienced in the mills where this ventilation is employed, besides obviating the fires and explosions arising from the accumulation of flour dust of the former system. All of the ventilating apparatus for one mill are connected with only one exhaust fan, no matter how many pairs of burrs are to be ventilated.

The meal discharge valve of Fig. 261 is a wooden flap valve held closed by its weight and the suction of the exhaust. The weight of the meal will force it open and the meal will pass out without permitting the air to enter.

The discharge valve shown in Fig. 262 is made of cast iron, and contains a conveyer screw similar to that shown in Fig. 260, but occupying a horizontal position. By it the meal is forced against an iron flap valve which prevents the air from entering the curb through the meal discharge spout. In both cases the chop, itself accumulating around the flap valve, forms a very effectual packing, and prevents a leaking of the valve. When the cast-iron valve is used a greater degree of exhaust can be attained than with the sim-

ple flap valve, as the weight of the meal would not be sufficient to open the valve when the flap valve is held closed by a strong suction. But with the aid of the screw discharge valve the discharge valve can be opened against any amount of suction. Lately an addition has been made by Mr. Behrns in the shape of an automatic rapper. At a trifling addition of price an apparatus will be furnished which at intervals will automatically close the exhaust valve, *r*, Fig. 260, and cause a hammer placed over the pin *e*, to strike several blows against that pin, when the valve will be reopened again.

The old-fashioned way of cooling the chop by having the hopper boy or a cooling room is done away with. The disadvantage of leaving a cooling room as a reservoir into which meal is run all night and bolted next day, is that it requires double capacity for bolting and purifying, and also for regrinding middlings. The advantage of bolting as you grind is that you can see what you are doing and make a more even grade of flour. Whatever grade of flour you make be particular to make it even.

CHAPTER XXVIII.

ATTRITION BY AIR-BLAST.

Attrition by Air-Blast.—In the device illustrated in Fig. 263 there are two triangular or fan-shaped sectors, *a* and *b*, placed so as almost to touch at the outer edges and to be about a quarter of an inch apart at the apex, the edges being closed by the adjacent surfaces. All of these places are corrugated with ranges of ribs having cutting edges, standing toward the apex. At the apex there is a chamber, *e*, formed between the plates, between

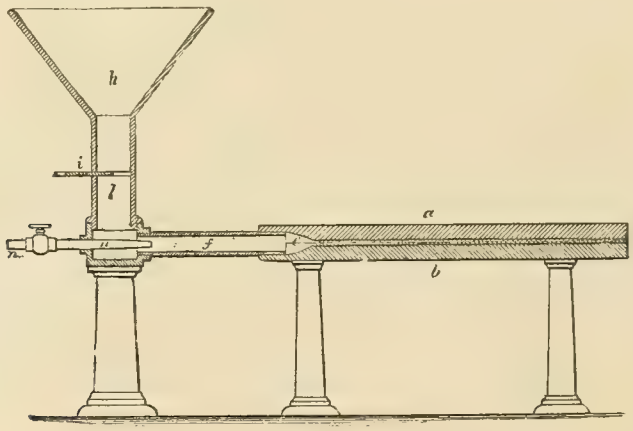

FIG. 263.—FAN-BLAST ATTRITION MILL.

which the induction tube, *f*, is connected; *h* is a grain hopper, with a regulating slide, *i*, and tube, *l*, opening into the tube *f*. Air under a pressure of 250 pounds to the square inch is admitted to the pipe, *m*, and draws the grain through the induction tube, *f*, and forces it powerfully between the roughened converging plates, *a*, *b*; crushing, spreading and driving forward the grain until the flour is blown out at the narrow opening between the outer edges of the plates *a* and *b*. It is preferable that the plates should be of steel or chilled cast iron. The area placed between the plates near the apex corresponds with the area of the long narrow opening at the outer edges of the plates.

This process seems to be operated exclusively by a company making health foods. The decortication effected by it is surprising in its cleanness.

CHAPTER XXIX.

IRON DISC MILLS.

Iron Disc Mills—Raymond Brothers' Mill—Jonathan Mills' Disc Machines.

Iron Disc Mills.—There are many classes of work where there is demanded great capacity, together with high speed and low cost of mill, and where there is no skilled labor required (or even attainable) for the purpose

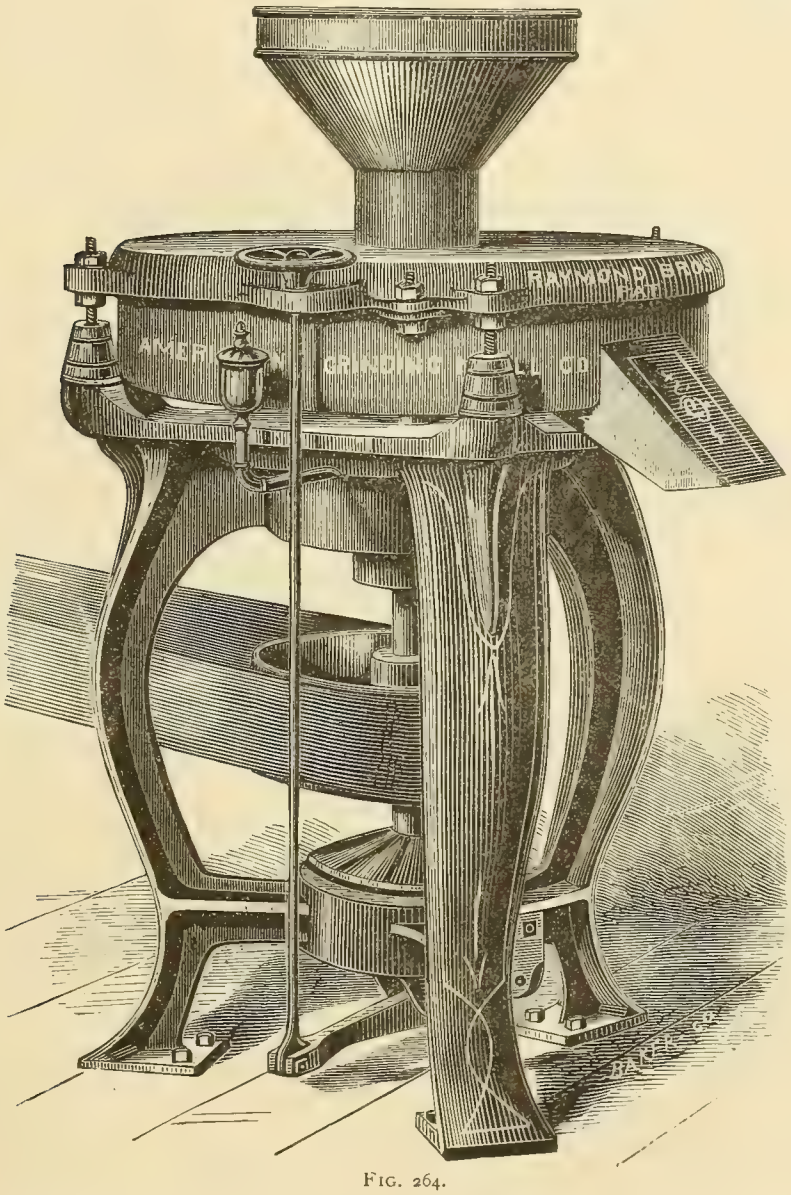

FIG. 264.

of dressing, mounting and running the apparatus. Such mills are very frequently needed at a great distance from repair shops or supply houses, and must consequently have some provision for repairing damage or breakage by

duplicate grinding surfaces, always at hand. It is, also, advantageous to be able to vary the character of the material ground, without tedious or costly change of dress. To meet such cases, the iron disc mill comes in admirably.

Raymond Brothers' Mill.—In the iron disc vertical grinding mill, Fig. 264, patented by George and Albert Raymond,* December 30, 1879, there are many features which are at once interesting and valuable. There have been many metallic grinders made, all of which have endeavored to produce a grinding surface of metal which would retain sharp cutting edges and wear for a long time without being resharpened. Some are cast with the dress upon their face, the face being chilled; but in these mills the cutting edges become rounded, and the metal gets softer as the hard chilled face wears away. There are some which have steel strips or blades inserted in the body and properly backed. To make a cheap self-sharpening grinding surface the

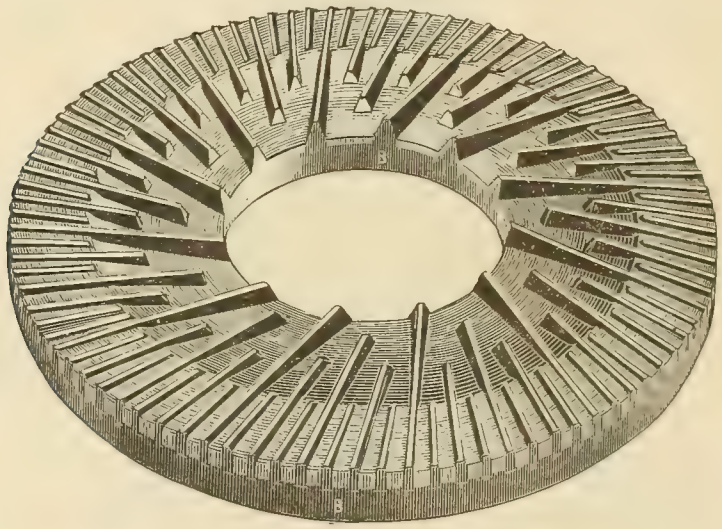

FIG. 265.—DISC OF RAYMOND MILL.

Raymonds make the body of soft iron and the cutting portions of chilled iron (Fig. 265). By this arrangement the soft metal wears away more rapidly than the harder metal, leaving the latter exposed. (We find this same arrangement in the tooth of the common squirrel; the soft body at the back wearing away and leaving the strongly enameled front of the tooth sharp and cutting.) In making the Raymond discs there is a soft-iron body formed by casting, leaving spaces for the subsequent reception of the hard metal. After this soft body has become cold it is placed face down in the mold and used as a chill, molten iron being poured in it to form hard grinding or cutting portions. These grinding discs are cheap, and have a wonderful capacity. Visitors to the Cincinnati Millers' exposition of 1880 will remember a corn mill and this principle in one of the galleries. One ingenious feature in the mill proper is the insertion of a wooden pin in the coupling, which pin will break off if any hard foreign body (as a nail) gets between the discs, thus preventing damage to the mill. Spare plates with different dress can be readily put in to suit different material, or to replace those which may become worn out.

* Raymond Brothers, Waupan, Wis.

Jonathan Mills' Disc Machines.—It must not be supposed that the iron disc is limited in its usefulness to rough, fast milling, such as corn grinding. On the contrary, one class of iron disc mills has at a stride advanced to a position entitling it to the most respectful consideration, as it effects the gradual reduction of wheat under the most advanced processes of high milling proper.

The most prominent type of iron disc mills is that bearing the name of its persistent inventor, also attached to the process under which gradual reduction by his iron discs is carried out. We describe it at length, as specially applied to degerminating and gradual reduction.

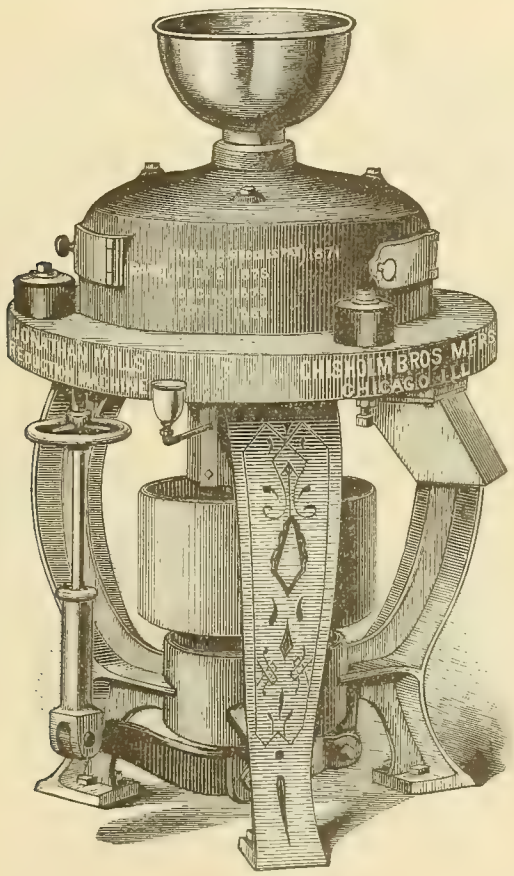

FIG. 266.

Iron disc mills are used not only for granulation and gradual reduction, but for removing the germ, the object being to take this out without injuring the bran or breaking down the berry. In order to effect this, it is desirable that the discs shall be driven upon a rigid axis and at a fixed distance apart, and that the grain fed to them shall be graded before splitting. For ordinary purposes it is sufficient that the wheat shall be graded into two classes, large and small. Fig. 266 shows a mill embodying these principles.

Fig. 267 shows the face of the disc employed for degerminating; Fig. 268 an enlarged view of the whole machine, vertically through the centre. For taking out the germ and some impurities, the discs are entirely of iron, sixteen inches in diameter, with marginal rounded corrugations, hav-

ing absolutely smooth surfaces on a depressed bosom in each disc. The lower disc F, Fig. 268, is the runner, and the upper one E remains stationary, being provided with a central feed-opening in which there is a hopper, Fig. 269. The bosom reaches to within a few inches of the skirt, so that the grain may have free passage in a horizontal position (or upon its side), but not otherwise. It will be remarked that this is just the reverse of the object to be attained in "ending" grain. The corrugations, V, of the skirt have a draft of about three inches, as shown in Figs. 267 and 272. Each ridge is about $\frac{5}{8}$ inch wide at the skirt, and the inner ends slope at an easy incline to the level of the depressed bosom of the disc. The discs are shown in section in Fig. 270.

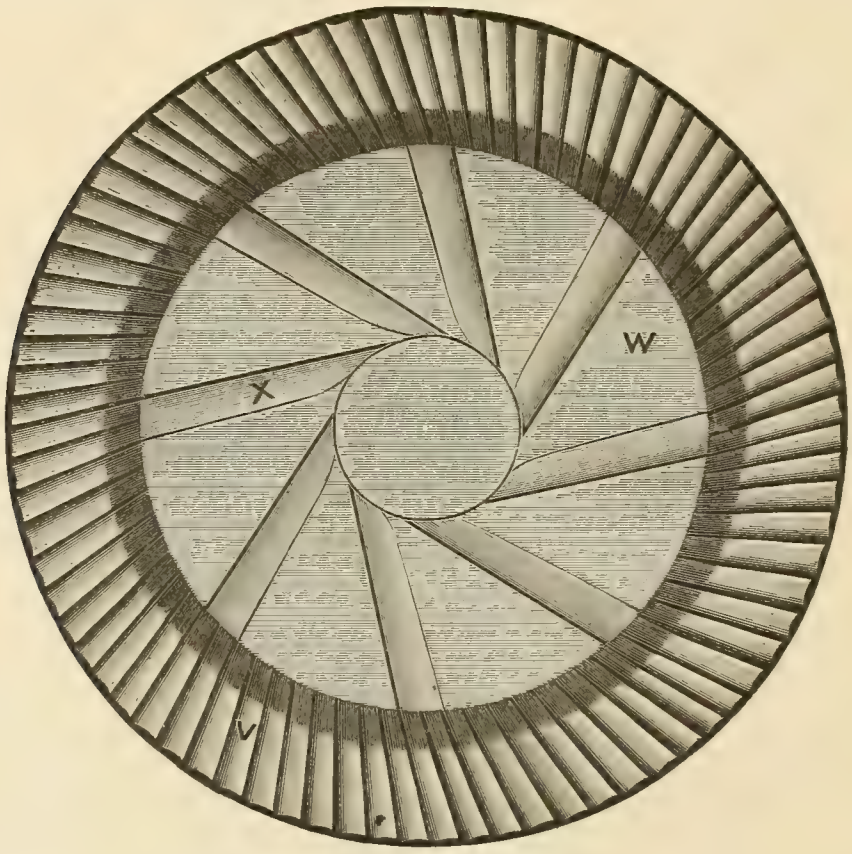

FIG. 267.—MILLS' DEGERMINATOR.

It will be seen that the ridges are inclined upon one side as in a burr ; but this incline has a round summit, instead of the feather and track edges of a burr-stone. In the depressed bosom there are eight furrows, X, running from the inner ends of some of the breaking ridges, V, and terminating in the draft circle. In being intended merely to break open the wheat along its lengthwise crease, and let the germ and dirt drop out, there are no sharp angles or roughened surfaces which would tend to break the berry and cut the bran. There are suitable adjustment screws to set the lower disc at the proper distance from the upper, to suit the grain being split. The hand-wheel, G, serves for this adjustment. The machine runs at about 500 revolutions per minute. Centrifugal force and the leaders, X, cause the grain to run horizontally into the depressions between the ridges at the skirt. The ideal splitting is as shown in Figs. 270 and 271.

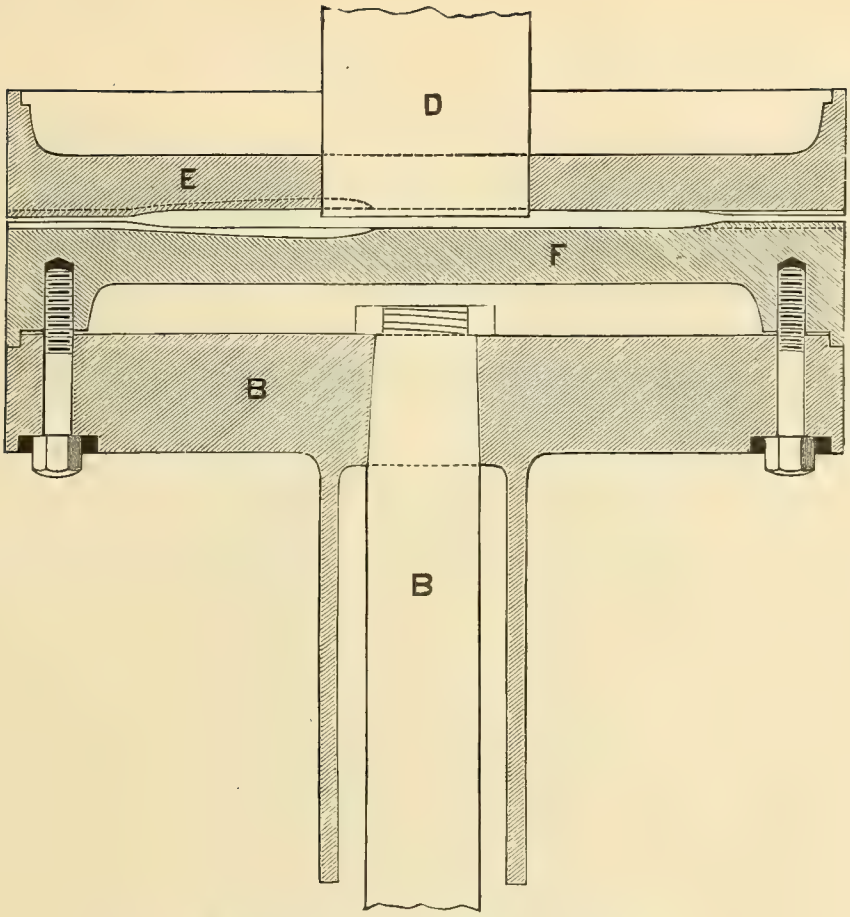

FIG. 268.—ENLARGED PARTIAL SECTION OF MILLS' MACHINE.

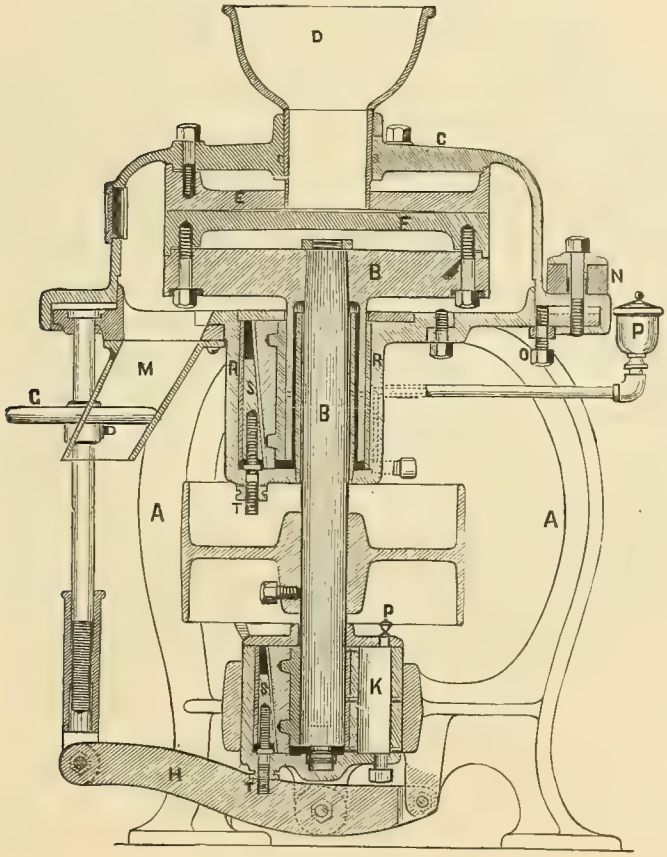

FIG. 269.—GENERAL SECTION OF MILLS' MACHINE.

Substantially the same apparatus is employed for breaking down the grain, there being only some variation in the dress, adjustment, speed, etc.

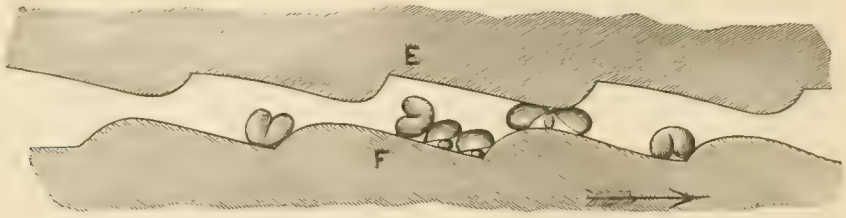

FIG. 270.—IDEAL ACTION OF DISCS.

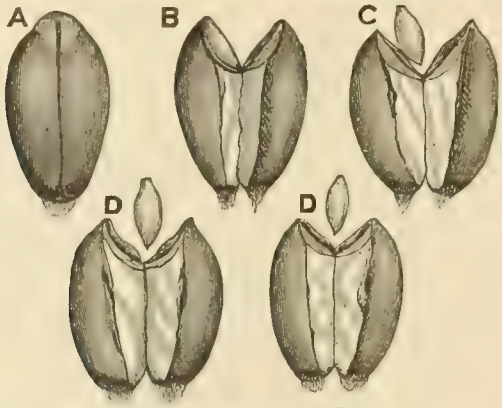

FIG. 271.—IDEAL SPLITTING AND DEGERMINATION.

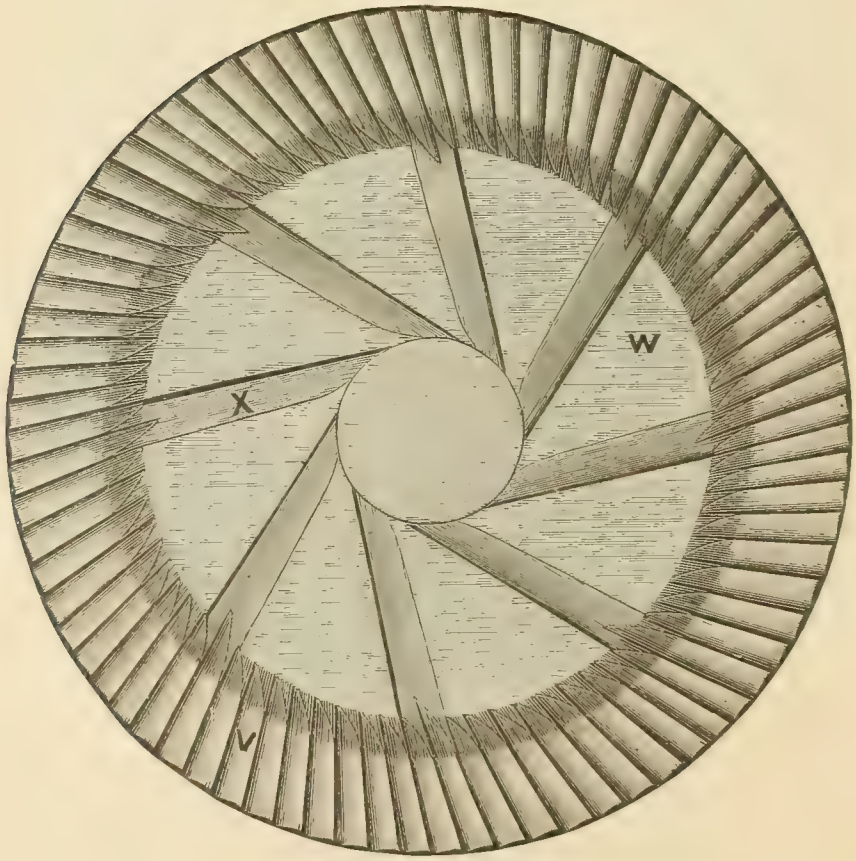

FIG. 272.—MILLS' REDUCTION DISC.

Fig. 272 shows the face of the reduction disc. These machines are manufactured by Chisholm Brothers, Chicago, Ill.

CHAPTER XXX.

DETAILS OF DIFFERENT TYPES OF BURR MILLS.

Classification of Mills. — Usual Type of Mill. — Munson's Geared Under-Runner Mill. — Munson's Portable Mill Spindle. — Plantation Mills.

Classification of Mills.—Mills, that is, the machines or frames, are classified according as the burr faces are vertical or horizontal, into "vertical" or "horizontal." The distinctions, "upper-runner," "under-runner" and vertical also apply to the whole frame, as do those of "oscillating" and "stiff" drive. In addition to this, the distinctions of "belted" and

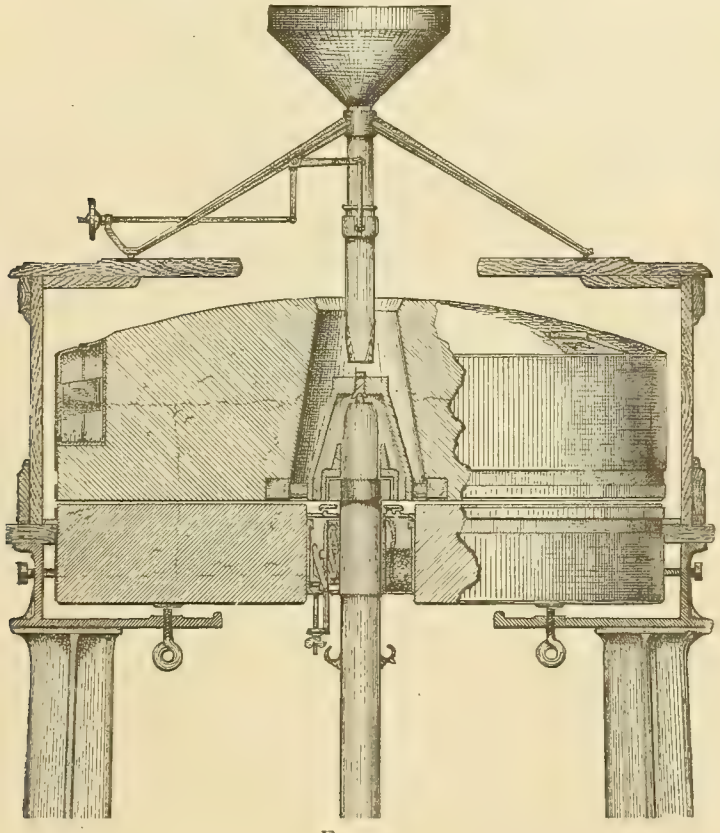

FIG. 273.

"geared" mills come in. The most usual type up to the present day seems to be the oscillating upper-runner geared mill, belt-drive coming more and more into use.

Usual Type of Mill.—Fig. 273 shows a common type of mill, having stones from three to five feet diameter, and running at from 1,759 to 2,264

feet per minute rim-speed, corresponding to 140 to 180 turns per minute for a four-foot stone. The capacity of such a four-foot stone is from six to fifteen bushels of wheat per hour, depending on the speed and dress of the stone and the quality desired in the product, and consuming an amount of power not yet properly estimated.

Munson's Geared Under-Runner Mill.—Fig. 274 represents in lengthwise vertical section a double-geared under-runner mill, made by Munson Brothers, Utica, N. Y.

A represents a cast-iron frame, on the upper part of which is a cylindrical shell, B, to receive the runner or under-stone, C. This shell is of larger

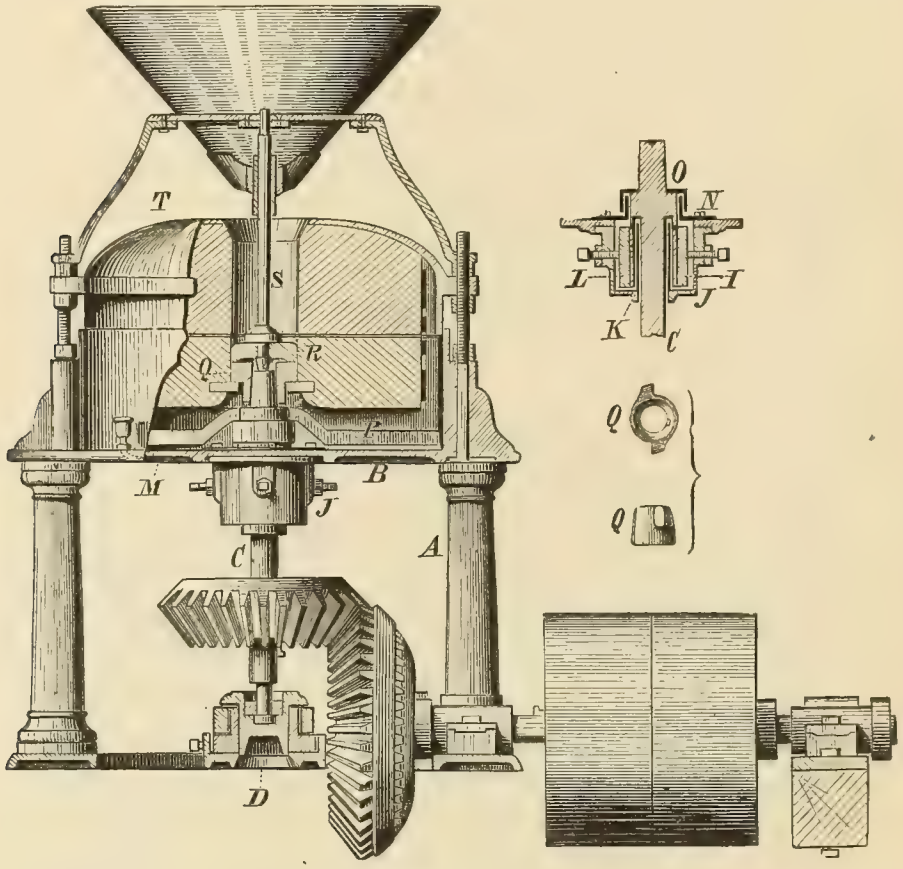

FIG. 274.

dimensions than the stone, C, so as to leave a space, *a*, all around and underneath the stone, C. The shell, B, has its upper edge made perfectly smooth and even, so that all parts of its surface will be in the same plane. The shell is cast in the same piece with the frame, A. In the lower part of the frame there is placed a horizontal driving shaft, D, which has a bevel wheel, E, secured to its end. This wheel gears into a bevel pinion, *a*, on a spindle, F, the lower end of which is stepped in a socket, *b*, the upper end of which has a flange, *c*, around it. This socket is fitted within an adjustable box, *d*, which rests upon a lever supported by a nut and screw, by which means the stones may be made to run at a greater or less distance from each other to vary the fineness of the flour. The spindle, F, is provided with a collar, I, which is

fitted within a box, J, attached to the underside of the shell. This box is of cylindrical form, concentric with the shell, and within it there are placed bearings, *h*, which are adjusted snugly against the collar by keys, screws or other means. The collar is hollow and opened at its lower end, having a space, *i*, all around between it and the spindle, as shown at *j*. The box is provided with a central vertical tube, *k*, around which the collar works, the tube passing up between the collar and the body of the spindle. The upper part of the collar is perforated with holes, *l*, which are just above the bearings, *h*, and above the upper end of the tube, *k*. K is a tube which extends along underneath the shell, and communicates with the upper part of the box, this tube, K, forms a means of supplying the box with oil at any time.

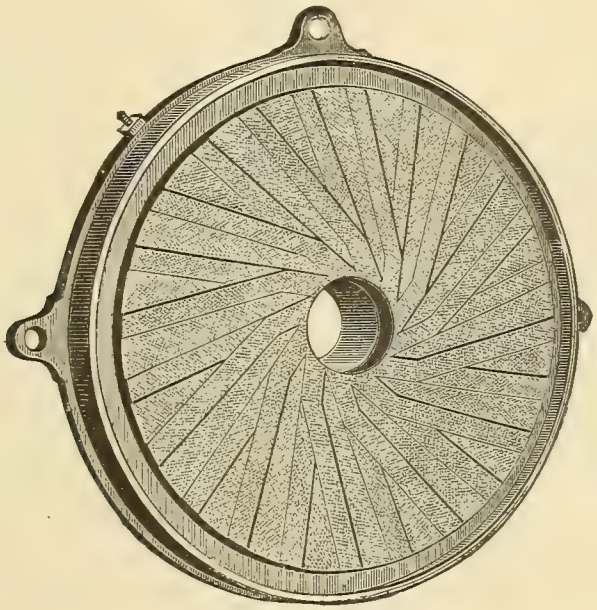

FIG. 275.—UPPER OR BED-STONE.

The collar within the box forms the bearing surface of the spindle. The box is covered within the shell by the cap, *m*, having a circular aperture in its centre to allow the spindle to pass through, this aperture having a flange, *n*, around it, covered by a cap, *o*, on the spindle. On the upper end of the spindle there is placed a clearer, L. This clearer is formed of two arms, *pp*, attached to an eye, *q*, which is fitted on the spindle and secured thereto by a feather and groove. The arms of the clearer extend nearly to the side of the shell. M represents the driver, which is fitted on the upper part of the spindle, and like the clearer is secured to the spindle by a feather and groove. The driver rests on the eye of the clearer, and the driver has two arms, *rr*, projecting from its opposite side. The arms are rounded at their face sides or bearing surfaces, the curvature being in a vertical plane, as shown at *s*. The arms of the driver fit within recesses, *tt*, of a shell, N, which is secured concentrically within the runner, and has a pendant bearing, *u*, which rests upon the apex of the spindle. The damsel, O, is attached to the upper surface of the shell, N. P is a cast metal cylindrical box, in which the upper stone, Q, is secured by set screws, *ww*. This box is turned true at its lower part so that

it may fit into the shell, the box being provided with a shoulder or flange, *a'*, all around it, which flange is parallel with the lower edge of the box, P. The stone, Q, has an eye, *b'*, made in it centrally, and the box, P, is secured in proper position by means of screw rods, *c'*, and nuts, *d'*, the rods, *c*, being attached at the shell, and passing through eyes, *e'*, at the outer side of box, P. On the box, P, a hopper frame, R, is placed, containing the hopper, S, and shoe, *f'*, which may be arranged as usual. It will be seen from the above description that the runner, C, will, in consequence of the arrangement of the driver, M, relatively with the apex of the spindle, F', be allowed to ad-

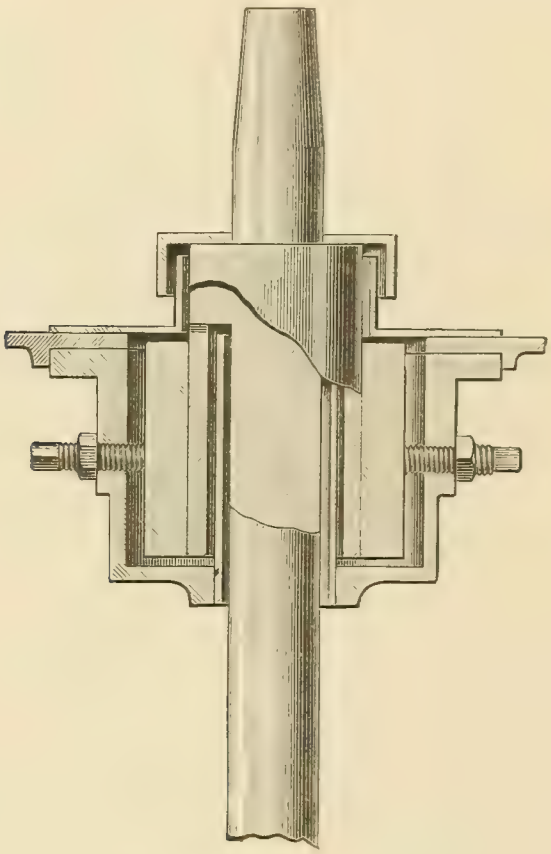

FIG. 276.—SPINDLE FOR PORTABLE MILLS.

just itself to the stone, Q, so that the parallelism of the faces of the two stones may be preserved as the stone, C, rotates. This arrangement, to wit: the having of the apex of the spindle in line with the bearing surfaces of the arms, *rr*, of the driver, admits of a universal joint movement of the stone, C, an effect which cannot be attained in the ordinary arrangement. This invention also enables the spindle to be always kept properly lubricated, as oil may be poured into the box, J, at any time, and the oil within the box is retained therein, in consequence of the perforations, *l*, in the upper part of the collar, I. These perforations cause the oil, which may have a tendency to rise in the space between the tube, *k*, and the collar, I, to pass the holes, *l*, into the box, instead of passing over the tube, *k*, which extends above the holes of perforations, *l*. This is an importat feature, as it effectually

prevents the escape of the oil from the box, J, when the latter is not over supplied.

The burrs are furnished in duplicate to suit those who run constantly, so that when one pair is out for sharpening the duplicates can be used.

Munson's Portable Mill Spindle.—"Some of the so-called portable mills answer very well on coarse grains and coarse grinding, but for fine work they do not meet the demands of the trade; they are constructed without regard to the tramming of the spindles or the importance of keeping them in their true working positions. The metal boxes, which are held up against the collar or the neck of spindles, are continually wearing out, and unless some provision is made whereby the spindles may be perfectly and accurately

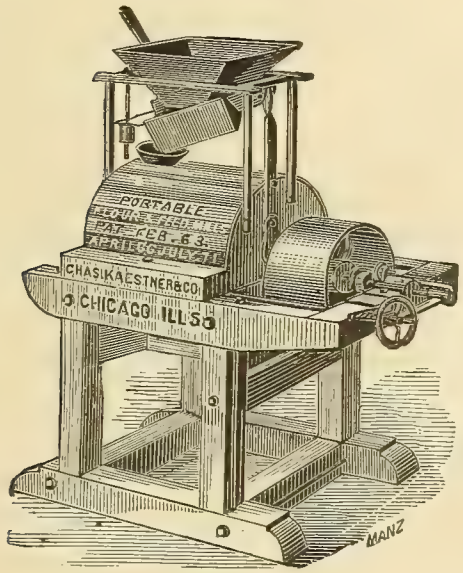

FIG. 277.—KAESTNER MILL CLOSED.

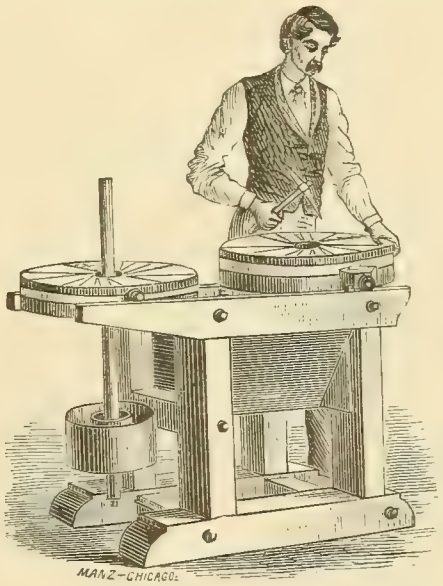

FIG. 278.—DRESSING BURR OF KAESTNER MILL.

adjusted, the work performed is of an inferior quality, and the loss of power by friction greatly increased. The curb of the mill, being cast in one piece, has its inside rim turned perfectly true, and by means of a tram-stick or index any deviation or any perceptible change in the position of the spindle, no matter how slight, can be easily detected and easily adjusted. The spindles are made of solid wrought iron or hammered iron, and are provided with inserted solid steel points, ground in on a taper fit with emery and oil, making an absolutely perfect bearing, which may be easily removed when injured. The neck or collar is forged solid on the spindle, and reamed out to fit within the bush; inside the bush babbitt-metal boxes are placed, which are held up against the collar by set-screws. The bush is provided with a central vertical tube, around which the collar works, the tube passing up between the collar and the bottom of the spindle, the collar in the bush forming the bearing surface of the spindle. The bush is covered by a cap having a circular central opening, through which the spindle passes. The bush once filled with oil will keep the bearing of the spindle lubricated until the oil is exhausted or worn out, with no delays from over-heating, and with no loss of

power by friction. These mills are constructed with the under-stone hung on a sensitive point or cockhead spindle, or they can be made with the under-stone rigid and stiff on the spindle."

Plantation Mills.—These are generally vertical and are run at high speed. Being run by irregular power, they should have positive feed, so as to feed in exact proportion to the speed the burrs are to run, thus preventing choking in the eye. Such a mill can be used handily in a saw-mill, where the motion is very irregular. A 16 or 18-inch mill, running 300 to 800 revolutions per minute, will grind five to ten bushels of corn per hour.

The Kaestner Vertical Burr Mill.*—Figs. 277 and 278 have the runner in a wrought-iron shaft, running in self-oiling boxes. The runner is rigidly attached to the shaft, but the bed-stone has an oscillating attachment or universal joint, permitting its accommodation to foreign bodies, etc. The bed is attached to the frame by dovetailed slide-blocks, which can be moved forward and back. To put the stone in balance, there are two pins connected to these blocks, which are provided with rollers, working in connection with a universal collar attached to the frame at the back of the stone and forming the universal joint. The runner is put in working position by a steel point attached to the lighter lever and coming in contact with a corresponding steel point on the shaft. A spring attached to the lighter rod yields to the entrance of a foreign body and then presses the bed-stone to its work. The burrs may be held apart while feed is shut off, allowing them to run idle without throwing the belt off—an advantage which many appreciate, especially in the South, and for farm and custom work.

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* Made by Chas. Kaestner & Co., 63 South Canal street, Chicago, Ill.

CHAPTER XXXI.

SYSTEMS AND PROCESSES.

Progress of Modern Milling — Hungarian Roller System — Why Hungarian System is Complicated — Details of 150-Barrel System — A 450-Barrel Roller Mill.

Progress of Modern Milling.—Several causes have opened the way to the powerful and progressive movement of modern milling. Among these may be mentioned the increasing demand for high grades of flour free from bran and from woody fibre. The demand for this glutenous* middlings flour becomes larger from year to year, for two reasons:—society becomes more and more luxurious as the years roll on, and the idea that it is necessary to scour the intestines with irritating woody fibre is losing ground. Another cause for progress in milling in the old country is that the consumption of breadstuffs has increased by reason of increase of population, while harvests have steadily declined by reason of the withdrawing a large number of workers from the fields, the ruining of harvest fields through the passage of armies over them, and the general impoverishing of the country necessarily dependent upon wars. While declining harvests stimulate the European miller to larger production and improved quality of flour, the opening out of the great American and Australian wheat fields, with their immense yields and exemption from expense for fertilizers, exert a powerful competition with transatlantic wheat growers.

It is not only desirable, but necessary, that, as a matter of economy, the yield and quality of wheat flour shall be improved, the cost of manufacture lessened, and the less available kinds of wheat be brought into use; and as a matter of business prudence each miller should keep as near as possible to the front rank in his trade.

Competition, stimulated by ample rewards for successful invention, is fierce, intelligent, well organized, and backed with abundant capital; hence systems, processes, and devices follow each other with wonderful rapidity and with marked and beneficial effects upon the rapidly advancing science of milling.

There are, perhaps, few words more loosely applied than "system" and "process" as used in the milling art. The dictionaries draw no satisfactory line between them. They are used indiscriminately in about the same way as the word "continent," in reference to which latter we may say that some geographers divide the land on our earth's surface into two continents, some five, and some eight. In like manner, some say there are two processes, some five, and some a dozen or more.

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* Glutinous means, strictly, like glue; glutenous means consisting wholly or in part of gluten.

In seeking a division line we may make it between the methods, and speak of "old" and "new" process as meaning whole wheat milling and middlings milling, no matter by what machines effected; we may speak of "low" and "high" milling to represent the same distinction, and we may divide the latter into "single reduction" and "gradual reduction" processes. We may ignore the question of the operation, or the flow of material, and mark out our systems according to the granulation devices, as the "roller system," the "Jones system," the "Jonathan Mills system," etc. The term "Hungarian system" is loosely applied to roller middlings milling by gradual reduction, whereas the original Hungarian system was middlings milling by gradual reduction with burrs. As both "high" and "low" milling are effected with rollers the matter is further complicated; and when we come to consider that the various operations in any one method as a whole—say middlings milling—may be effected by combinations of successive devices, the entire matter beggars description. Thus the breaks may be done on rolls or on burrs; the middlings reduction has equal choice, and the bran dressing may be by burrs, rolls, beaters, or brush machines.

The author, then, declines to commit himself to a definite reply to the oft-asked query, "How many systems or processes are there?" because the words system and process are ambiguous, interchangeable, and indiscriminately applied, and the methods of making flour from wheat are so various that there are scarcely two mills in a hundred (if there are that many) in which the methods are the same. It may be said in a general way that popular usage seems to limit the words "old process" to low milling by burrs; "new process" to the use of burrs to make a large proportion of middlings, separately floured on burrs; and "roller system" and "Hungarian system" to middlings working by gradual reduction with rolls, followed by middlings flouring with rolls.

There is no good in getting carried away by any one system and being in such a hurry to get it in operation that you have no time to consider all the conditions. Study it well first.

The harder the wheat is the better high grinding pays in connection with the roller system.

The original high grinding system was commenced in the mills of the Danube, most of them two or three pair mills, averaging under five pairs, and all driven by water-power.

In some Continental mills the gradual reduction system became so popular that in mills not having enough stones for the complete process to go on continuously, they first broke the wheat, dressed and sorted it, then redressed and resorted it until the process was complete.

Let it be the maxim that in the proper breaking of the wheat before grinding lies the secret of making white wheat flour.

Otto Muller states that 2.7 to 5.5 cwt. of wheat is ground on roller-mills for each horse-power, against 3.3 cwt. by millstones. Oexle is very frank about the roller system. He says: "The harder the wheat the greater the need for gradual reduction, and the softer it is the better the results

of flat grinding. And for the softest wheats, like some of those of the Southern States, flat milling is perhaps as good a way of grinding as any."

Hungarian Roller System.—The leading features of this system are as follows :

1. Systematic separation, scouring and brushing. In this it does not differ from any other good system of milling.

2. Wheat granulation by grooved chilled-iron rollers, employing at least five breaks, and rolls having from eight to thirty grooves to the inch, making but little flour and leaving the bran finished.

3. Separation of the light chaff from the breaks by aspirators.

4. Thorough and systematic grading and purifying the middlings by purifiers.

5. Sizing the large middlings by equally-speeded smooth chilled-iron rolls, thus reducing their size and taking out germs and bran specks.

6. Reducing the fine clean middlings to flour by differentially-speeded porcelain biscuit rollers.

7. Full and complete bolting after each of the above.

After cleaning, the wheat is sent to a grading reel to be separated into two or three sizes, to secure proper action in the ending stones, which would not otherwise touch the small grains, and would take too much off the large.

Cracking may be done on smooth rolls, and is really a cleaning operation, because the grains open out at the crease, setting free some dirt which the brusher has failed to reach, and the germ is dropped out or loosened. Cracking yields about one per cent. of fine material, one half being germ and dirty flour, and the other inferior semolina.

After the wire cylinder of the cracking mill, the wheat goes to the coarse fluted rolls. The number of flutes on the rolls varies from 300 to 900.

By the first cracking of the wheat there are got ten products : coarse middlings, No. 0 to No. 5, inclusive ; fine and coarse bran, fine middlings and first clean groats, which last get a second cracking.

There are generally three grades of flutes : two coarse, one medium and one fine. Each roll pair is followed by a scalping reel to take out the detached flour and semolina. The ordinary miller will run the flour from all the fluted rolls into his silks with that from the smooth rolls, thus producing one straight grade of good color. The advanced miller will separate more or less the different granulations, and take the cream off the best for his first qualities. Some new process millers make middlings all the way from 000 to 9, which is a good example of how not to do it.

At each stage of the cracking there is separation and purification. The bran goes into three grades of bran and several qualities of black flour. The final product of breaking is 6 to 12 per cent. of bakers' flour, 80 to 86 of unpurified middlings, and 7 to 8 of bran. The baker's flour and middlings pass together into the scalping-reel, and the middlings from the scalping-reel into the grader. This grader yields 30 per cent. of finished white middlings, 20 per cent. of larger middlings not so white, and 35 of coarse and brown middlings.

To separate the middlings from the bran particles, either smooth rolls or very finely fluted rolls are used. These yield but little flour, but still each time the product should be scalped and the middlings graded. There is more middlings purification than in this country. Making the middlings into flour is the last and easiest operation. It is done on smooth differential rollers, and is a simple easy crushing.

It is claimed that by this process there is over 50 per cent. of flour which would, if mixed, be better than new process, and the rest (leaving out 12 per cent. of black flour) better than the wheat flour of the new process ; that 25 per cent more flour is made by the same power, and the yield increased twenty pounds to the barrel.

The First Roller Mill.—The first roller mill was started in Pesth, the building and business being changed from a foundry to a flouring mill.

Why the Hungarian System is Complicated.—The reason why the Hungarian system is so complicated may not at first be understood ; and to understand it at all, there must be taken into consideration the wheat, the climate, the soil and the habits of the people.

The Hungarian wheat is so brittle that, if ground low, the flour would contain bran particles too fine to be bolted out.

There are used in the Hungarian mills three kinds of wheat, the best, the Bariat, subdivided into two sorts, one very small and of dark skin, and very hard, growing on both sides of the Danube, from Pesth beyond the Theiss river. The Theiss wheat, growing between the rivers Theiss, Maros and Szamos, is larger, less brittle and a little lighter in color. The Austrian wheat is more tender than the Hungarian.

The hardest wheat comes from Stuhlweissenburg, fifty miles from Pesth, the soil being black as coal and the country level. There is very little of this wheat. These three are generally mixed, the Temesvar to give semolina and middlings, the Debreczin to give more flour at once, and the Stuhlweissenburg to improve them both in strength and color. The latter is of medium size, lighter skin than the other two and more tender, very hard, breaking well into semolina, and of the greatest whiteness inside.

All through Austro-Hungary, Germany, Italy, and other Southern European countries, brown brèad is used in every house, white bread being used in small quantities only ; but there is great demand for Semmel, Kipfel, Bounzel, Bratzel and Salztanzel, all of best flour and of various shapes and sizes. Back as far as 1807 we find semolina made and sold as Wiener Gries. It was hand separated.

There is, then, a demand and a market for several grades of flour, from eight to thirteen being made in some mills. In France the black flour and hard bread of Hungary and Austria would find little or no market, a paternal government regulating the quality and price of bread, the quality being almost uniformly high and the price reasonable. In America, where bread-making is so much less understood than in France, the laboring classes, while refusing to eat such "*schwarzmehl*" as satisfies the working population in South-eastern Europe, have not been educated up to eating the high-grade

bread that the French "blouse" exacts, because such light crisp-crusted wholesome bread is attainable in few American cities, even at any price.

Details of 150-Barrel Roller Mill.—The regular roller process has this disadvantage, that it cannot be operated in the small mills with which this country, more than others, abounds. In mills making less than 150 barrels per day it is not applicable.* Such a mill will take seven double sets of break-rolls, using one each on the first, second and fifth, and two each on the third and fourth; two on germ middlings, two on coarse middlings, one on fine middlings, and one set of porcelain (biscuit) to clean up the fine tailings. This might be used in connection with two pairs of four-feet stones for fine middlings, and one for tailings and the other low grade flour. Passing through one set of 9 × 18 inch corrugated rolls, with eight flutes to the inch, the product goes through the first scalping reel, not over six feet long, and clothed with No. 18 wire. What passes through this should go to a roll covered with No. 10 silk, to take out the fine dark flour. The tailings from this reel will pass to the chop reels, there to meet similar material from all the breaks. The second break-rolls take the tailings from the first scalper; they have twelve grooves per inch, because the material is finer. The second scalper should be clothed with No. 20 wire. The tailings from this go to double sets of rolls for the third break, having sixteen groves per inch of circumference. There is more grading done on the third and fourth breaks than on the others. The fifth has little else to do but to clean the bran. It may be well to have two short scalping reels for the third break and two for the fourth, because this will pound the coarse stuff as it passes along.

Flouring unpurified middlings by too much handling should be avoided. All that passes through the scalping reels should go to the chop reels. The fourth break-rolls should have twenty flutes to the inch, and the fourth scalper No. 24 wire. The fifth break may be on double rolls with twenty-four grooves, and this is followed by the bran-duster. The chest of this mill may have eight reels, four on each side. The upper ones may be clothed with No. 0. The tailings from this, going to the germ rolls, and that which passes through to the two next reels below, clothed with No. 4. The tailings from these will be coarse middlings and should go to the purifiers. The flour and fine middlings passing through the cloth will go to the rolls below, which have the head clothed with No. 11 and the tail with No. 9. Some flour will pass through the No. 11, and the fine middlings will be dusted on the No. 9, and should be sent to the purifiers as soon as possible. That which passes through the No. 9 should be sent along with that which was not free from specks from the No. 11 to the next reels below, clothed with No. 12. This takes out all the flour. The tailings from the No. 12 may go with the cut-off from the flour reels to a fine middlings machine, thence to the porcelain rolls, there not being enough to keep a pair of burrs busy.

For the coarse middlings there should be three purifiers, one below the

* Since writing the above, "concentrated roller mills" and "pony break-rolls" have been introduced, enabling gradual reduction by rolls to be carried out in part in small mills, say of fifty to one hundred barrels capacity per twenty-four hours.

other ; the upper clothed with Nos. 4, 3, 1 and 00, in equal lengths, the tailings going to the shorts bin. The second and third machines may be clothed one number finer. The tailings from these should be sent to the low grade stones, the clean middlings going to the rolls for crushing.

There are five parts of break-rolls, having respectively ten, twelve, fourteen, sixteen and twenty grooves to the inch.

After each of these breaks, the material passes through scalping reels clothed with wire and cloth. What tails through one scalping reel goes over to the following break. What passes through the first three scalping reels passes into a reel which we designate A, clothed with nine feet of No. 0 cloth at the head and five feet of No. 20 wire at the tail. The tailings from the reel pass between the fourth break-rolls at the same times as the third break. What passes through the fourth and fifth scalping reels goes into the reel B, clothed with twelve feet of No. 10 at the head and four feet of No. 00 at the tail. What tails over from the fifth scalping reel passes between the bran rolls, having twenty-four corrugations to the inch, and then through a bran duster clothed with No. 22 wire, the bran going over to the bran bin, and the flour passing through reels which we will designate C and D, C being clothed with twelve feet of No. 12 cloth and four feet of No. 4, D being clothed with sixteen feet of No. 14 cloth. What goes through the head of the reel C, goes over as low grade. What passes through the tail end of reel C goes through a pair of sizing rolls, and then through reel D, after which it passes with that from the head of reel C into low grade. What passes through the head of reel A goes into reel E, clothed with twelve feet of No. 9 or 10 cloth and four feet of No. 4. That which has come through the No. 20 wire cloth (equals 0000 silk) goes to purifier No. 1. That which passes from the head of reel B goes to a separate chest for bolting with what passes from reel E. What passes through the foot of reel B goes to purifier No. 4. What passes from the foot of reel E goes to purifier No. 3. The tailings from reel E go to purifier No. 2. The tailings from purifier No. 1 go to the bran rolls. The purified product from No. 1 goes through sizing rolls, then through twelve-feet reel F, clothed with eight feet of No. 10 and four feet of No. 00. The product from the head of reel F goes with that from the heads of reels E and B to a chest for bolting. The material from the foot of reel F goes over into purifier No. 2 with the tailings from reel E. The tailings from purifiers Nos. 2, 3, 4, 5 and 6 go through tailings rolls, and then over into the bran-dusting reel. The product of purifier No. 2 goes through sizing rolls, then into reel G, having eight feet of No. 10 and four feet of No. 0. Material from the head of reel G goes into the bolting chest ; that from the foot goes into purifier No. 3 with the material from the foot of reel E. The products from purifiers go together through sizing rolls, then into reel H, having eight feet of No. 10 and four feet of No. 0. The material from the head of this reel, H, passes over into the chest for bolting. That from the foot of reel H goes into the head of purifier No. 5. The product of purifier No. 6 goes through sizing rolls, which reduce it to flour. It then goes through reel K, clothed with twelve feet of No. 12, what dusts through going over into the chest for bolting and the tailings going over into the tailings rolls.

As I said before, all of the product from the tailings reels goes into the bran duster with the product from the bran reels.

A 450-barrel roller mill should have six double sets of round corrugated rolls for breaking and bran dressing, three double sets of smooth iron, and one double set of fine scratch rolls for tailings. The purified middlings may be ground on four pairs of 30-inch under-runner middlings burrs, making 350 revolutions.

The Jonathan Mills System.*—The outlines of this system are as follows:

1. Separation, scouring and brushing, as in any advanced method of milling.

2. Wheat splitting and germ extraction by the chilled iron rounded-ribbed "degerminator" disc shown in Fig. 267. (See chapter on Disc Milling.)

3. Scalping out the germ and dirty break-flour loosened out by the degerminating operation.

4. A series of breaks or "gradual reductions" on round-ribbed chilled cast-iron reduction discs, shown in Fig. 272 of chapter on Disc Milling, each break being followed by

5. Separation by wire scalping reels, suitably clothed, of the middlings, break-flour and broken wheat, and the last break proper being succeeded by

6. Bran cleaning on suitable special machines.

The sizing, grading and purification of the middlings, the bolting, &c., are devoid of special peculiarities; the clothing and arrangement of the reels and purifiers are carefully suited to the material and with a view to the desired product.

The writer regrets to omit the details of this process, as they are not yet (April 1, 1882) made public, as are those of the Hungarian system and its modifications, the Allis, Stevens (Noye), &c.; he has seen it in operation at the mill of M. C. Dow & Son, Cleveland, O., and elsewhere.

Jones System.†—The Jones system, which may be seen entirely carried out in the Linden Mills, Louisville, Ky., which were built and fitted specially to demonstrate it, has for its salient feature the employment of single cylindrical rolls working against a curved breast. The Jones machine is shown in Fig. 281, page 388, and referred to under the head of Single Rolls.

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* Chisholm Bros., Chicago. † Jones, Ballard & Ballard, Louisville, Ky.

CHAPTER XXXII.

DETAILS OF ROLLERS AND FRAMES.

Roller Milling — Varieties of Roller Machines — Number of Rolls, Single and Three High — Jones' Single Roll Frame — Roll Pairs — Method of Driving — Length of Rolls — Diameter of Rolls — Surface of Rolls — Materials of Rolls — Soft-Iron Rolls — Forms of Corrugations — Stevens' Patents — Number of Corrugations — Twist of Corrugations — Feed and Pressure — Axial Pressure — Differential Speed — Speed Ratios — Capacity of Round Rib Rolls — Yield from Roller Milling — Amount of Break Flour — Color — Strength of Roller Flour — Power Required by Rolls — Labor Required with Rolls — Coolness with Roll Work — Rolls on Soft Wheats — Break Rolls for Soft Wheats — Break Rolls for Mixed Wheats — Rolls on Middlings — Bran Cleaning by Rolls — Gray's Roller Frame.

Roller Milling.—In considering roller or cylinder milling there are many things to be taken account of, viz., the number, relative diameter, relative direction of rotation, speed, surface, and material of the rolls themselves, their uses, methods of mounting, driving, feeding and adjustment; all these being considered in connection with a statement of the various processes of roller milling.

Varieties of Roller Machines.—Rolls used in milling are either single, working against flat or concave stationary surfaces, or working against one or more rotating rolls. Where working together they may be of either equal or different diameters; they may run toward each other or in opposite directions; their speed may be the equal or unequal; their surface may be ribbed, slightly rough, or polished; they may be of steel, soft or chilled iron, porcelain (biscuit) granite, or syenite. They may be used for breaking, degerming, flouring, sizing, or bran-dressing. The shaft of only one of the rolls may be driven, or both may have their shafts driven. Rolls may be used alone in connection with other equivalent apparatus for low, half high, or high milling.

It will at once be seen that there are many combinations and variations of kinds of rolls possible. Many of these are in active operation with more or less success; many more have been tried and abandoned.

Single and Three High Rolls.—As regards the number of rolls working together, the single roll working against a breast is not in very extended use, although for certain purposes it is doing good work, and may be made to do better, especially for the reduction of middlings to flour. Three high stands of rolls, in which a central roll works against one above it and one below it, these three taking the place of two pairs, are in successful operation, performing low milling, in Europe. They are not as yet common in America.

Fig. 279 shows the action of a single roll against a plain surface, P, sometimes used for cracking. There is but little contact, hence cool action; but

the capacity is naturally less than by any other method for a given peripheral speed. The greater the distance between *m* and *n*, the greater the friction;

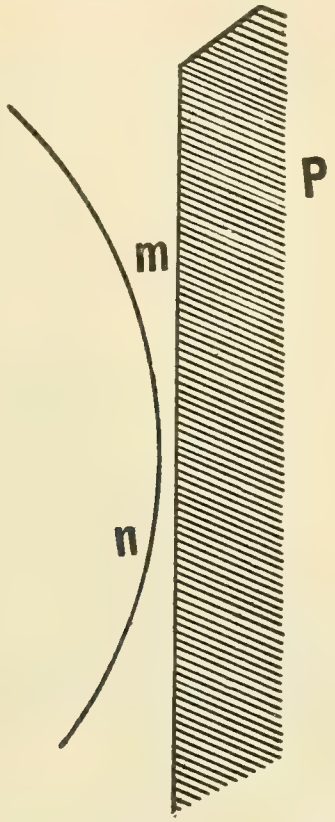

FIG. 279.—SINGLE ROLL AND PLANE BREAST.

the greater the capacity (for a given fineness of grinding), and the less the pressure required.

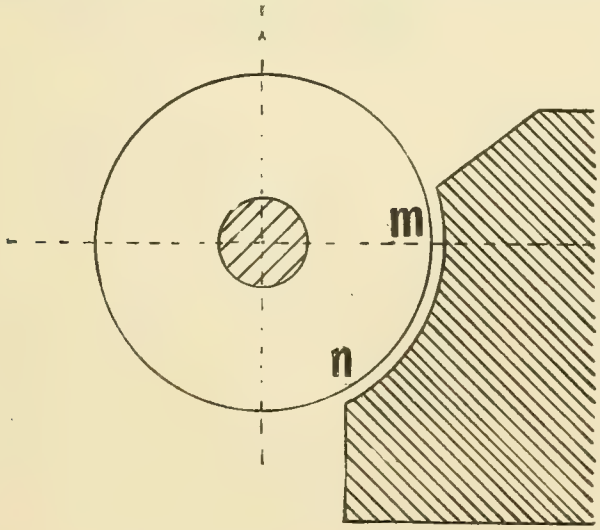

FIG. 280.—SINGLE ROLL AGAINST CONCAVE.

Fig. 280 gives a sectional view of the type of single roll against a concave, such as is made in stone by Jones, Ballard & Ballard, of Louisville, Ky., and

in use in various parts of this country for reducing middlings. The machine is shown in Fig. 281, the adjustment being by hand-wheel and screw at each end of the frame.

Roll Pairs.—The most common and successful type of roller machines, employed in more varieties and for more purposes than any other, is where both rolls are side by side, and are of the same diameter. Thus arranged, their work depends upon their material and surface, directions and speeds. The most common arrangement is where both rolls run toward each other; in some cases the speed being equal, and in some, one roll running faster than the other. Where they run toward one another they have a squeezing or

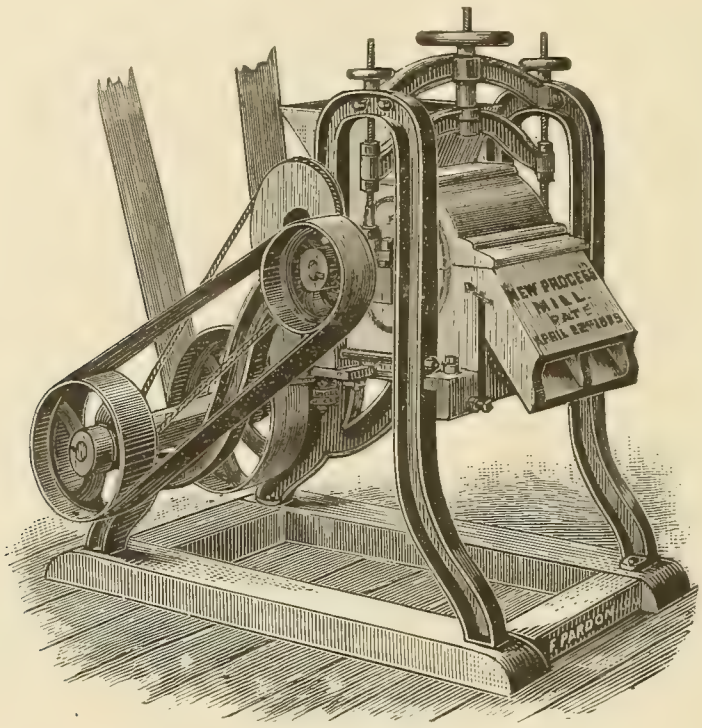

FIG. 281.—JONES' "SINGLE ROLL" FRAME.

crushing action, suitable for flattening the germ in middlings and for sizing the middlings themselves, although their action tends to cake soft material, which will then require to be disintegrated by special machinery which follows it.

Running in opposite directions, as though driven by an uncrossed belt, the "up" roll having a slower surface velocity than the "down," the action is to turn the material over and over while carrying it down and reducing it in size. This action is better produced by having both rolls run toward each other, as though by a crossed belt, but roll surface going faster than the other, so that the tendency to turn the material is the same, while the feed is faster and easier. Such rolls are used for breaking the grain, flouring the middlings and cleaning the bran.

Method of Driving.—Where both rolls run in opposite directions, that is, downward and toward each other, one of them may be driven by

any desired means, and the other revolved by friction between it and the other roll, or the material being worked upon. Where both of them are to rotate in the same direction, that is, where they do not run toward each other in the grinding space, both shafts must be driven ; and this may be done by separate gears, by separate belts, by connecting gears, or by connecting belts.

Connecting gears and connecting belts are the means most commonly adopted. Connecting gears have the advantage that the relative speed of rotation removes the same under all circumstances ; but at high speed they are apt to be noisy, unless specially adapted for this work, and to consume power. Connecting belts have the advantage that they run smoothly and without noise ; but there is some liability to lose the relative speed of rotation by slipping of the belts, unless they are very wide, and have consider-

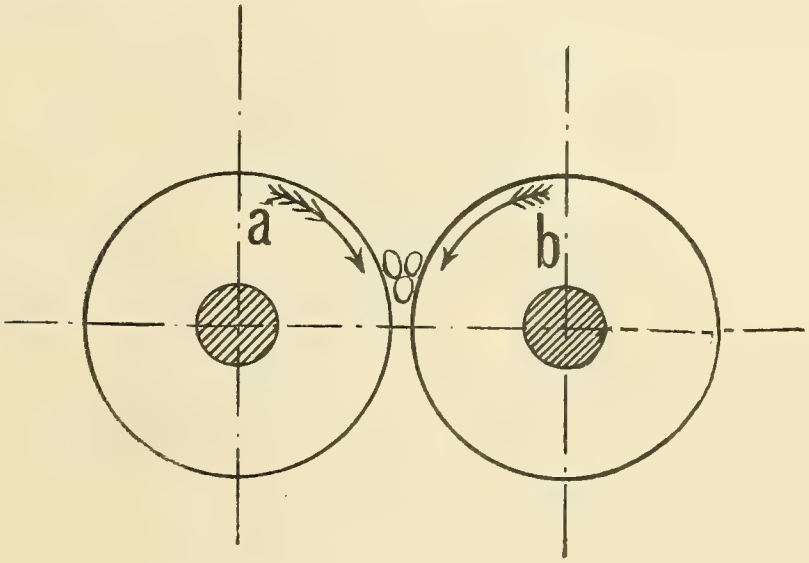

FIG. 282.—ROLL PAIR RUNNING IN OPPOSITE DIRECTIONS.

able tension, with pulleys of larger diameter than are generally used for the purpose.

Length of Rolls.—Many roller manufacturers of to-day are trying to get extra capacity for their rolls by increasing their length ; but the difficulty of feeding them properly increases in proportion to their length, especially if the feed-roll be run too slow, as is generally the case. By the use of high-speed feed-rolls and special feeding devices, long rolls are now fed much more easily than formerly. The Stevens rolls are made from 15 to 30 inches in diameter, varying with the capacity of the mill.

Diameter of Rolls.—The greater the diameter of the roll the greater the length of contact space, and the less the angle between the surface ; hence, the greater the friction on the material the easier the feed ; the less pressure required, the less power needed, and the greater the capacity for a given fineness of grinding, with all the other conditions equal. The "Stevens" (round nib) rolls are nine inches in diameter for all operations. Rolls less than eight inches in diameter seem unadapted to any of the operations in milling.

Surface of Rolls.—The surface of the rolls may (1) be ground, ribbed or fluted; or (2) it may have a roughish surface or grain; or (3) it may be smooth and polished. If ribbed, these ribs may (*a*) be parallel to the axis, or (*b*) they may have a spiral or twist given them. There may be (1) concave flutes in the convex cylindrical surface; or (2) convex ribs raised upon the convex cylindrical surface; or (3) they may partake of the nature of both these, and be waved or doubly rounded; or (4) they may have the outline of the teeth of a wood rip-saw; or (5) that of the teeth of a

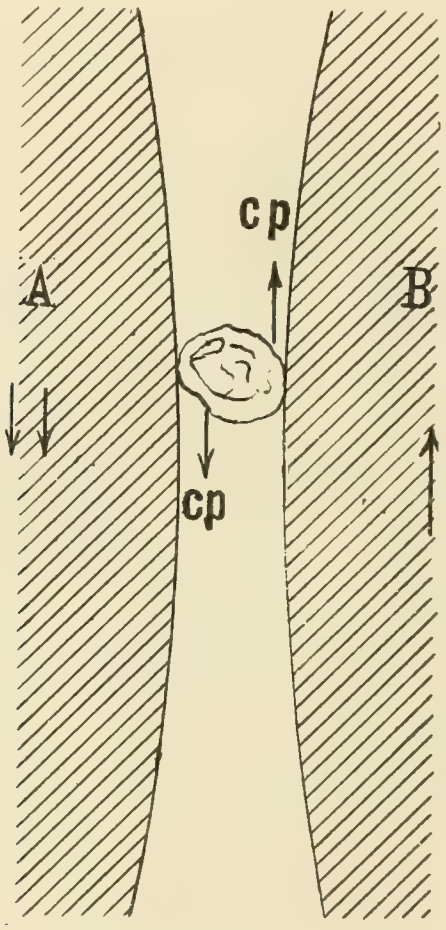

Fig. 283.—Action of Smooth Rolls.

cross-cut saw; or they may have any one of a number of other sections of rib, groove or flute, each having some special claims to our attention.

Materials of Rolls.—Of the various materials used, chilled cast iron and porcelain biscuit are the most frequently employed; the first either fluted or plain, and the second with a plain "grain" surface. Stone is apt to wear unevenly and too quickly.

The influence of the material of the roll upon the pressure necessary to effect a given reduction, is shown in tests made with middlings and other materials, with rolls of cast iron, porcelain biscuit, granite, etc. It was found that to produce the same amount of middlings flour with cast-iron rolls as with porcelain, more than one-fourth more pressure was required. Dull

chilled-iron rolls work easier than smooth ones, although buyers seem to desire that new chilled rolls shall be polished.

It is well known that the finer and sharper burrs are, the whiter the flour from them will be. For the same reason, porcelain rolls give a somewhat whiter flour than chilled iron. This greater whiteness is not due to a smaller percentage of bran particles, but to greater fineness of grinding; nor is the dark color of flour at all due to particles of iron or carbon taken from the rolls, as supposed by many; because paper manufacturers, who are as particular as millers are about the whiteness of their product, employ rolls of the very same material as those used for flouring, and at a very much greater pressure. The darkening of flour by the material of iron or steel rolls is impossible.

There are corrugated rolls made from stone, porcelain, and glass; but they soon wear.

It must be remembered that variations in the material of a smooth roll, and of the substance being operated on, cause variations in the coefficient of friction between the roll and that substance. The greater that friction the less areal pressure needed.. If c represents that coefficient of friction, and p the pressure, the power used will be equal to c times p.

The following table, from Kick, shows the coefficients of friction of rolls of various kinds, on fine semolina (going through No. 7 gauze), and No. 2 middlings.

Material of Roller.	Coefficient of Friction on	
	Hard Semolina.	No. 2 Middlings.
Chilled Iron, Polished, . . .	0.213	0.194
" " "Matt," . .	0.287	0.268
" " Rifled, . . .	0.325	0.304
Porcelain Biscuit, ...	0.404	0.364
Granite ("Matt" Surface), . .	0.424	0.384
Syenite ("Matt") . . .	0.445	0.404

The coefficient of friction is evidently much greater with "matt" than with polished cast iron, and greater with porcelain than with either; being less with middlings than with semolina, all kinds of rolls; and the proportion with different rolls running about the same with semolina as with middlings.

Soft-Iron Rolls.—It is very often found that the regrinding of fine middlings cannot be finished with smooth polished roller surfaces, but that good results can be got by using for this purpose cast-iron rolls of homogeneous and porous structure, which come more nearly to the condition of porcelain than the highly-polished chilled rolls which are on the market. When it comes to simply reducing large middlings or semolina to smaller size, any hard homogeneous material will do well enough.

Forms of Corrugations.—The corrugations must be so arranged that they do not interlock. With a corrugated roll of hand rip-saw tooth section of grooves and differential speed, the action upon the grain is shearing or cutting instead of mashing or crushing, even although the cutting edges

themselves become dull. This is the case so long as the fast roll has a speed at least double that of the slow one. Where the fast roll has a speed of less than twice that of the slow one, the action is no longer cutting or shearing, but crushing, mashing, or bruising. Where the rip-saw outline of tooth is used, the roll having the faster motion must have its teeth pointing downward in the grinding space, and the other upward. If, on the contrary, the

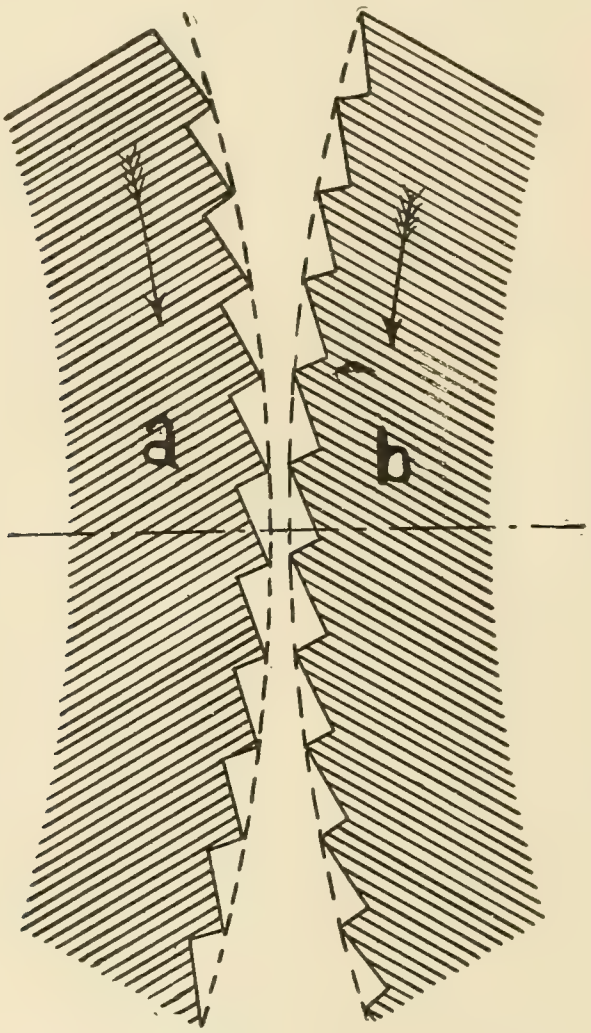

FIG. 284.—DIFFERENTIALLY SPEEDED SAW-TOOTH ROLLS.

inverted teeth were to run faster than the others, then there would not be a cutting, but a crushing action.

The finer the material to be ground, the finer the corrugations must be made for a given roll diameter. It might be said that the depth of the corrugations must be half (or less) the diameter of the particles to be reduced. With very short use the sharpness of the corrugations becomes lost, and modern practice points to the employment of grooves intentionally rounded in section.

Of course the great desideratum in a roller mill is to effect granulation without cutting the bran. It is claimed for the rounded ribs as against the saw

tooth that they roll the bran back and spill out the contents of the berry, and that even the cockle instead of being cut or crushed is held, the whole passing off in the final operation with the bran.* It is further claimed that the germ is neither cut nor broken, but that it is crushed, passing off in one operation from the scalper to be finally separated from the middlings. Just so far as these claims are borne out by actual commercial results, there is increase of

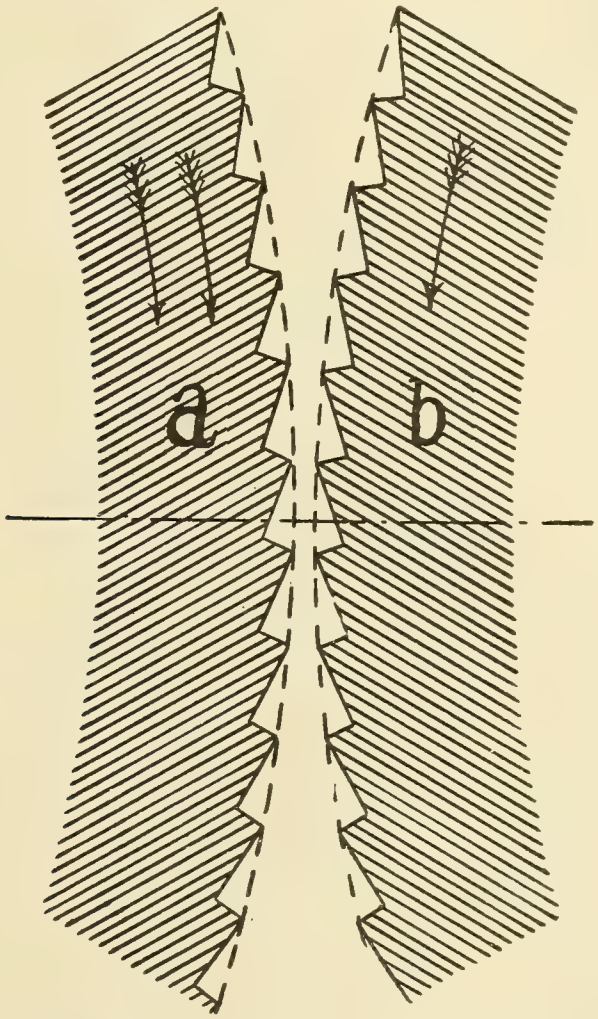

FIG. 285.—EQUALLY SPEEDED SAW-TOOTH ROLLS.

yield and small proportion of low grade flour. It is claimed for a sharp tooth roll that it makes more middlings than the rounded rib; but, on the other hand, for the rounded flutes that they make cleaner middlings than the "sharp cuts." There is this comparison between the sharp and the round tooth rolls and the millstone, that the one may be said to represent the old millstone dress in which there was a large proportion of cracked surface, and the other corresponds to the more modern idea of perfectly smooth surface of both the land and the furrows.

One of the greatest drawbacks in the introduction of roll pairs is that

* This latter claim, for any corrugated rolls, strikes the author as rather too strong.

while they render the hard spring wheat valuable for making better flour than that made from millstones from even the best spring wheat, they have not been able to get from soft winter wheat as good results as the millstone; hence the roll pairs, while building up the great flouring industries of our Northwest, have done little or nothing for districts that used to be the flour centres. This was especially the case with the saw-tooth corrugation; but with the advent of the round rib it is found that winter wheat can, in many cases, be handled better than by millstones, and even give results well comparable with those from spring wheat.

In the round dress for rolls there are fewer corrugations per inch than with the saw tooth. It is claimed for a round rib that it does not reduce any

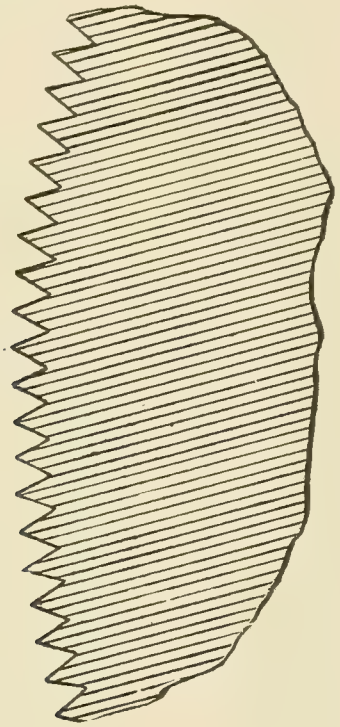

FIG. 286.—V-TOOTH ROLL.

of the fibre nor break the germ; that while the sharp cut rolls will handle any wheat that the round ribs will, the quality will not be so good. The sharp cut roll gives more bran impurity from hard wheat than from soft. This is on all grades of wheat. In reducing particles of pure flour or impure matter the scratch roll is the best, having shallow waved corrugations, about thirty-two to the inch. These are of great use on tailings.

Where the grooves are "saw tooth" in outline the groove edges of the slow roll point up, and those of the fast down, Fig. 284. By their combined action the wheat is cut and broken. Fig. 286 shows the V-tooth roll.

Stevens' Patents.—The Stevens' patent No. 225,770, March 23, 1880, contains as claims the combinations of rolls geared to revolve at different peripheral rates of speed and having the dress composed of fine parallel grooves laid near together, with appreciable plane surfaces between, so as to cross each other on the contiguous surface of the rolls; the combination of

rolls geared to revolve at different rates of speed and having the dress composed of fine parallel grooves laid near together and run in the same direction upon each roll.

The Stevens patent No. 228,001, May 25, 1880, refers to forming the rolls with parallel grooves having rounded dividing ridges trending lengthwise of the rolls; laying the ribs in such a direction upon each roll that they cross each other upon the contiguous surfaces; and when employed in the process of reducing grain to flour, a series of sets of such rolls, graded in respect to fineness or number of grooves to the inch, with intermediate bolts, the several sets acting in succession of grade.

The Stevens rolls are made by John T. Noye & Sons, Buffalo, N. Y.

Number of Corrugations.—The finer the grinding required, the greater the number of corrugations needed for a given diameter of roll. With the Stevens round rib roll, on hard spring wheat, the five breaks have respectively 10, 12, 14, 16 and 20 grooves per inch, and the middlings rolls 32. For soft winter wheat sometimes there are six breaks, in which case the corrugations per inch on the break rolls are respectively 8, 10, 12, 14, 16 and 20, the middlings rolls having 32, as with middlings from hard spring wheat. The bran rolls have 24 grooves per inch.

Twist of Corrugations.—The advantage of giving spiral twist to the flutes is to prevent the grooves of one roll from catching those of another, and to more effectually twist apart or break the berry. The amount of spiral or twist given the grooves in the Stevens rolls should vary with the character of the material being broken. Soft wheat takes more twist than hard, because it is more sticky, and more twist gives more shearing action, which frees the corrugations from the sticky matter.

On spring wheat, with the Stevens system, on all breaks except the last one, there is only enough twist to the currugations to prevent locking together when in motion. On the last break for cleaning bran they have a twist of about five inches in thirty. On winter wheat, all breaks have from five to six inches twist in thirty inches length. The Stevens round rib rolls have one inch twist for the breaks, four to six inches on the bran-rolls, and one inch for middlings.

Feed and Pressure.—The drawing in of the grain or any other material between the rolls is by reason of the friction between the surface of the rolls and the material to be acted upon. Where the rolls are equally speeded, there is very little slip between the material and the roll surfaces.

Where one roll is directly driven and the other is driven by friction through the chop, the speed of rotation of the other roll will be in proportion to the pressure, and will depend upon the material being ground, and the material and surface of the rolls themselves. In this case, of course, there will be rubbing upon the chop. Where both rolls are driven toward each other at different velocities, the speed of the feed will depend upon the speed of the fast roll; but there will be some friction between the rolls and the particles of the chop. The greater the difference in speed the greater the slipping of the chop upon the roll surface.

The greater the diameter of the rolls, the greater the friction between

them and the material to be worked, the easier the feed, and the greater the capacity of rolls of a given length, speed, and material.

The material of the rolls has a greater influence upon the work than the speed has.

Axial Pressure.—The pressure upon the axes of roller mills is caused by two things: the weight of the rolls themselves, which is unimportant, and the sidewise pressure upon them exerted by the material being worked. All rolls should have an arrangement by which the minimum distance of approach of the rolls should be regulated, and the rolls should be held to this minimum distance by springs or weights, so that the passage of any hard body, as a nail, will not injure the rolls, which will spring apart and let the foreign substance through.

In order that they may be thrown apart at will, with the certainty that the distance will be the same when they are thrown together again, there should be an index device to each regulating screw, so that it may set in exactly the same position.

Attention should be paid to the pressure of every roller mill. For breaking or reducing middlings, excessive pressure would not have material consequence, because it is counter-balanced by set screws. But in grinding fine middlings, no greater amount of pressure should be applied than is absolutely necessary, because great wearing of the bearing ensues, and a large amount of power is consumed.

Differential Speed.—Differential speed of rolls gives results in milling which cannot be obtained in any other way. In 1876 Wegmann adopted it for his rolls with decidedly good results. The old Pesther Walzmuehle was built in 1830 and arranged entirely on the Sulzberger system; and it worked successfully and paid from year to year for a long period of time from 30 to 50 per cent. dividends. This mill had grooved rolls for granulation, for regrinding the bran and for coarse middlings; smooth rolls for reduction of the coarse middlings and for semolina grinding; but Sulzberger's machine had three pair of rolls in each frame. Wegmann's improvements were: first, the use of only one pair of rolls during one crushing action; second, of self-action pressure rolls, and, third, the use of a hard and gritty substance, as biscuit.

At first the equally speeded rolls, worked by mere pressure and friction, were employed. This does well enough for reducing semolina into smaller particles. The differential speed adds to the capacity of the machine and avoids caking.

"Professor Kick, in the new edition of his book on 'Flour Making,' states that, on theoretical considerations, the power consumed in crushing grain by direct pressure—that is, between smooth rollers without differential motion—is exactly double that required to reduce grain between fluted rollers with differential motion. This roughly coincides, says H. Simon, with the results obtained in practice, and carefully conducted experiments have proved that direct pressure, without differential speed, produces one-third less result of the same pressure with it. But the direct pressure without differential motion has this further drawback, that you produce cakes instead of flour, and

that you have to submit the product to a special process of disintegration, which again unnecessarily consumes power."

Speed Ratios.—As regards the ratios of speeds of the rolls, this differs with the number of corrugations and the kind of wheat to be milled. With hard wheat the speeds are from two and a half to five times as great on the fast roll as on the slow. In working soft wheat, the fast roll runs from three to ten times as fast as the slow.

There is very little difference in the speed of smooth rolls.

The "concave and single roller" mill might best be employed on middlings. By this we mean to say, not that the concave is better for middlings grinding than any other means of grinding middlings, but that the concaves are better adapted to grinding middlings than to working any other material.

The Stevens' rolls have for the breaks and middlings flouring, speeds of 400 and 160 turns per minute = 5 to 2 or $2\frac{1}{2}$ to 1; the bran rolls 450 and 180 or the same ratio; on germ, 300 and 250, or 6 to 5.

Capacity of Round Rib Rolls.—The Stevens rolls, nine inches in diameter, and fifteen inches to thirty inches long, running on hard spring wheat, and at the speeds and with the corrugations before noted in this chapter, will handle from 200 to 700 lbs. of material per hour delivered to the "first break," and each successive set of rolls will handle all of the material given it from the preceding roll.

Details of Biscuit Rolls.—Porcelain rolls, twelve inches diameter, may be worked up to thirty inches in length with advantage. Above that, there is too much difficulty in securing equal distribution of the middlings. Although one pair of 30-inch rolls has not as much grinding surface as two pairs of 18-inch, the great expense of the frames makes it advisable to employ one pair of 30-inch rather than two of 18-inch. The small porcelain rolls are 12 inches long and $8\frac{1}{2}$ inches diameter; the large ones 17 inches long, 9 inches diameter. The large ones make 250 revolutions per minute and the small ones 260. The large ones have a 6-inch single belt and the small ones a 5-inch, both having a 16-inch pulley, the revolutions being, as before stated, 260 for the small and 250 for the large. The capacity of the small machines is 220 pounds of middlings per hour, and that of the large ones 320 pounds per hour. Single machines have, of course, one-half the capacity of double ones. The horse-power estimated to run the machines at the above-named capacity is two for the small and three for the large. The weight of the small double machines is 2,000 pounds, all ready to run, and that of the large double machine 3,200 pounds.

Capacity of Biscuit Rolls.—As regards the capacity of the porcelain middlings rolls, two pairs of 9 × 24 inches should handle all the coarse stuff in a 200-barrel mill, if the wheat be hard. If it be soft it will require three pairs to do this work.

Yield from Roller Milling.—At an experiment with roller mills, at Rouen, France, 2,400 kilogrammes* of medium quality soft wheat were reduced by the rolls.

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* One kilogramme = 2.2046 lbs. av.

The following table gives the results obtained by the crushing:

No. of the Crushing.	Quantity Crushed.	Residue after each Bolting.	Flours.	Unpurified Middlings.	Bran.	Loss, &c.
1	Wheat, 2,400	2,168	1,390 kilogrammes, or 16 per cent.	1,817 kilogrammes, or 76 per cent.	188 kilogrammes, or 7.5.	5 kilogrammes, or $\frac{1}{5}$ of 1 per cent.
2	" 2.168	1,381				
3	" 1,381	685				
4	" 685	307				
5	" 307	188				

The work completely shows as follows:

Bakers' flour	390 kilogs	= 16 per cent.	Flour of first quality.
Middlings flour	1,240 "	50 "	
Flour from finishing operations . .	246 "	10 "	
Shorts	360 "	16 "	
Bran	188 "	7½ "	
Loss	12 "	½ "	

The bakers' flour and the flour made in the finishing operations give, when mixed with middlings flour, flour of the first quality. Thus we get 76 per cent. of the weight of the wheat in flour. One hundred kilogrammes of wheat in the roller mill at Hall, in the Tyrol, gave the following results:

Flour, No. 00, ...	3	This mixture produces flour for white bread, 77 per cent.
" " 0, ...	20	
" " 1, ...	25	
" " 2, ...	12	
" " 3, ...	12	
" " 4, ...	5	
" " 5, ...	2	
Shorts, bran, loss, &c., ...	21	
Total, ...	100	

The yield from a mill at Prague, in Bohemia, was as follows:

Flour, No. 00, ...	3.9	The mixture of these products gives a flour called straight flour, for white bread, 77.5 per cent.
" " 0, ...	12.0	
" " 1, ...	12.0	
" " 2, ...	12.0	
" " 3, ...	12.1	
" " 4, ...	12.5	
" " 5, ...	9.5	
" " 6, ...	3.5	
" " 7, ...	1.2	
Shorts, bran, loss, &c., ...	21.3	
Total, ...	100	

"The Decatur Mill of Shellabarger & Co. is to-day making a barrel of flour from four bushels and forty pounds of winter wheat (not the best), and making 90 per cent. of quite as good a patent as when making only 30 per cent.

Out of No. 1 wheat, the Decatur Mill makes a yield of one barrel of flour from four bushels and thirty-six pounds of wheat." *

From hard wheat, one mill makes from 85 to 90 per cent. of flour, selling for more money in the same condition of the market than their old patent when making not over 35 per cent. of patent. The straight flour brings fifty cents more (with the market about the same) than before changing, while the mill is taking less wheat by eight pounds than before.

One German miller finds that one pair of roller mills grinds as much as one pair of stones, and gives a yield of 2½ per cent. more flour two numbers higher grade.

We doubt the equality of capacity, but can accept without hesitation the statements as to grade and yield.

The results of tests of a set of rollers and a pair of French burrs of 1,260 mm. (49.6 inches) diameter, fed with the same bran, shows the following after twenty-four hours' run:

	Stones.	Rolls.
Flour,	3.2	6.5
Fine middlings,	1.9	2.7
Coarse middlings,	2.9	3.3
Coarse middlings,	7.3	10.6
Fine bran,	48.4	57.8
Coarse bran,	35.8	18.5
	99.5	99.4

This shows for the stones 15.3 per cent. of flour and middlings, and for the rollers 23.1 per cent., that is, 7.8 per cent. more, while the grade is said to have been higher, and the power taken by the rolls much less.

Amount of Break Flour.—Straight wheat all of one kind, from Dakota or Northern Minnesota, should not make over 8 per cent. of break flour, in five breaks by rolls. Soft Michigan winter wheat will give 25 to 30 per cent. in six breaks. We may say that with hard wheat the amount of break flour produced in all the breaks is about 12 to 15 per cent.

The number of rolls required to make 150 to 175 barrels of flour in 24 hours varies from five to six of the grooved, according to the quality of the wheat being ground. In addition to this, there must be two or three smooth rolls for treating middlings and tailings from the purifiers.

An eminent Austrian miller says that the grinding or squeezing of middlings in rolls and then disaggregating the cakes which are found by letting the roller work against a segment, is an advantage only up to a certain degree. The roller with strong pressure is effective only until the semolinas are very finely reduced, and the particles are so very small that there is nothing more to squeeze. Then the stone, which many discarded too hastily, should be used for grinding the soft middlings as well as the bran.

Color.—Roller milling so reduces the grain that there is little impurity, either of the bran or of the germ, that gets among the valuable material. It is extracted in the form in which it can be easily provided for. The mid-

* Figures given by Mr. John Littlejohn.

dlings and the flour are then reduced in the pure state, and can be made in a much coarser manner and stronger than on the stone.

Variations in the rate of speed of rolls does not have a great influence on the quality of the flour, as in the case of burrs.

Strength of Roller Flour.—Those using new process flour should take notice that it requires a much larger quantity of water than winter wheat flours, that it must be thoroughly kneeded, and given ample time to rise before being placed in the oven. At the test in Cincinnati in 1880, Washburn, Crosby & Co.'s "Superlative" brand yielded 163 pounds of dough per 100 pounds of flour, the "Parisian" 164½ pounds and the "extra" 163½ pounds. This is a yield of forty pounds of bread more per barrel than the best winter wheat flour averages.

Power Required by Rolls.—Rolls consume less power than stone, in mills having just the same amount of preparation. One of the best modes of testing this is where a mill has been changed from stones to rolls, without changing any of the cleaning, bolting or purifying machinery. Some estimate a saving of 25 per cent. in power with rolls over stones, but doubtless 15 per cent. would be nearer right. We may perhaps say 20 per cent. as the outside margin.

In the experiments at the mill in Prague, elsewhere quoted (see Yield), to crush 2,400 kilogrammes in an hour required 10 to 12 sets of rolls, taking from 20 to 24 horse-power. To break up the rough middlings from this 2,400 kilogrammes of wheat, took 5 or six sets, requiring 10 horse-power. To convert in an hour all the middlings from 2,400 kilogrammes of wheat, took a détacheur and 8 or 10 converting rolls, using in all 24 to 30 horse-power. Thus, for the reduction of 2,400 kilogrammes per hour, 23 to 28 sets of rolls are necessary, taking 52 to 64 horse-power. Adding for elevators and other machines 26 horse-power, we have 78 to 90 horse-power. To do the same work with millstones would take 28 run of stones, four being dressed at a time. For the 24 pairs of running stones, 120 horse-power would be needed.

Labor Required with Rolls.—With the roller system there is less labor than with burrs, because there are no burrs to dress. Mr. Littlejohn gives, as the amount of labor needed for a 450-barrel roller mill:

2 Engineers, at $2.50 per diem,	$5.00
2 Firemen, " 1.50 "	3.00
2 Millers, " 2.50 "	5.00
1 Head miller,	8.00
1 Common hand,	1.25
2 Bran packers, at $1.25 per diem,	2.50
4 Flour packers, " 1.25 "	2.50
14 men,	$29.75

Coolness of Roll Work.—In roller milling there is a cooler condition of the products; and thus there is not only no danger of overheating and thus killing, but there is no loss by evaporation. The loss from this latter source in stone milling has been stated as from 3 to 5 pounds per barrel. We should, however, consider this as a merely fictitious loss. There is no

liability to heat any product in the roller mill except the bran; as, if the feed were stopped, none of the rolls would touch except the bran rolls. Sometimes, where most of the reduction is done on one or two rolls, as is sometimes the case, there will be some heating of the chop. There will be less liability to this where there are six or seven reductions than where there are but five.

Rolls on Soft Wheats.—An advocate of burrs said some time ago: "In cases where the harder wheats are used, such as those of Minnesota or Wisconsin, for instance, the system of gradual reduction should be found to be profitable. Millers using winter wheats, such as are grown in Illinois, Ohio, and Michigan and other States, will also find it to their advantage to grind higher, and regrind the bran by means of rollers. The entire roller system—that is, the complete reduction of wheat without the aid of millstones, has a future before it only on hard California wheat and hard Minnesota Fife wheat."

This statement may be true as regards cutting rolls, but round rib rolls are doing good work on soft wheat.

Break Rolls for Soft Wheats.—Most winter wheat needs six breaks, while that from Michigan needs seven, the grooves having a twist of about three inches in thirty.

Break Rolls for Mixed Wheat.—In Milwaukee some mills are running on mixed wheat, with rolls having the same corrugations as for hard wheat only, but there are six breaks instead of five.

Rolls on Middlings.—By the use of rolls millers are enabled to work up their coarse middlings and tailings from the middlings purifier into the very best flour. They crush the middlings so that they will pass through the meshes of the bolt, but flatten the bran and germs so that they will not pass through. The lower the grade of middlings to be ground, the more the results are to the advantage of rollers as compared with millstones.

There is one material that can be handled by porcelain rolls, that cannot be done with stones, and that is the fine product, too fine to feed into the eye of a stone.

Bran Cleaning by Rolls.—If rolls are used for no other purpose about a mill, they will pay upon bran, cleaning it well, and produce a good flour.

The bran resulting from roller work is broader and less shiny than that from burrs, and on inspection it is found to be cleaner and less white.

Bran cleaning by rollers, especially with winter wheat, is best done by several operations, the bran becoming lighter after each operation. In large mills the first set of bran rolls may be eight to ten inches in diameter with 300 to 500 corrugations, those for the last operation having 800 to 900 grooves for the same diameter. It is found that these fine rolls wear out quickly, and that a pair of burrs is a good adjunct to them. Oexle finds that the greater the difference between the roll speeds the better the bran is cleaned; so that while he commenced with 1 to 3 he now makes 1 to 250 and even 1 to 300. Oexle makes the grooves on the down roll finer than those on the up roll, and makes those on the fine roll straight and parallel with the roll axis. He

claims for these a very exact feed, regular wear of the rolls, cleaner scraping, and less pressure needed than with coarser corrugations. This last, of course, giving longer life to the rolls. In one patent of Oexle both the rolls may in about twenty minutes be made to run down; so that they may be

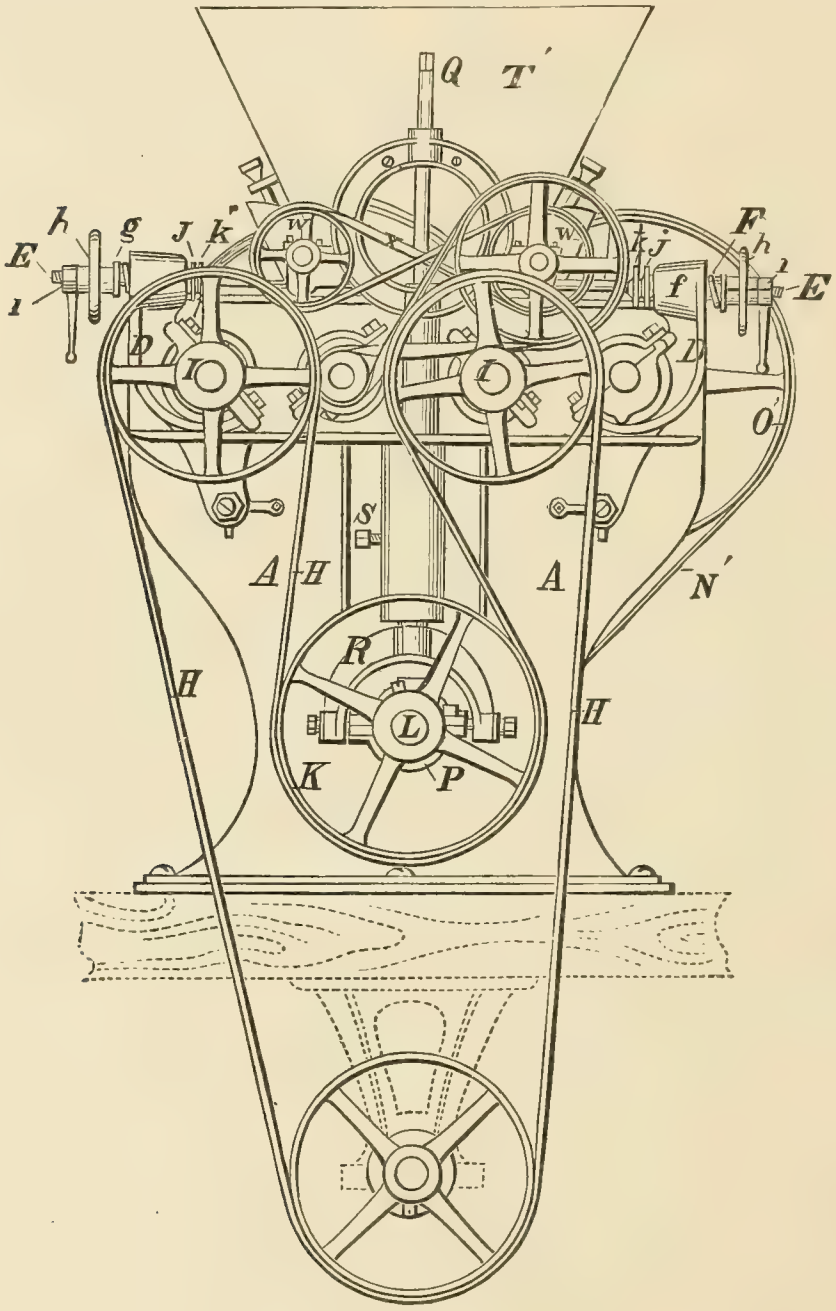


FIG. 287.—GRAY'S ROLLER FRAME.

run in one direction for more than one break and in the other for the others. This will allow the system to be introduced into smaller mills.

Gray's Roller Frame.—The new two-pair middlings roller machine, Figs. 287, 288, built by E. P. Allis & Co., Milwaukee, Wis., has the following dimensions: height, 5 feet 6 inches; width, 4 feet 9 inches; length, 4 feet 9

inches; driving pulley, 18x5½ inches; motion, 250 to 275 revolutions; capacity, 3 to 4 barrels per hour; power required, 3 to 4 horse (estimated). This same style of mill is built with 8½ × 14 inch rolls.

The middling machines, with porcelain rolls, built by E. P. Allis & Co., have the following dimensions: height, 5¼ feet; width, 3 feet 9 inches; length, 4 feet 6 inches; diameter of driving pulley, 16 inches, by 5 inch face; capacity 2 to 3 barrels per hour; power estimated at 2 to 3 horse; speed, 250 to 275.

Belts are used by reason of their being noiseless, and permitting high speed without heating the bearings, thus increasing the capacity. All the belts are open or uncrossed (Fig. 288). The counter shaft passing through the base of the machine is hung in pivoted boxes raised or reversed by hand

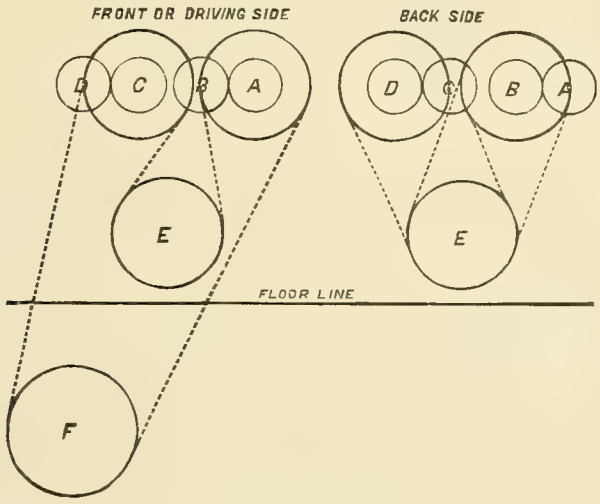


FIG. 288.—METHOD OF DRIVING GRAY'S ROLLER FRAMES.

screws to tighten all the belts while the machine is in motion. There is a 4-inch belt on the driving side, which drives the two high-speed rolls, one of which is outside and the other inside, and both running in the same direction. The main driving belt passes under the pulley on the counter shaft, driving the same in opposite direction from the fast rolls. On the back end of this counter-shaft there are two pulleys of equal size driving the slow rolls.

To lessen slipping, these pulleys are made as large as possible, generally twice the diameter of the rolls, although to get high speed they should be made smaller. The boxes of the inside rolls are made stationary. Those of the outside rolls are each supported by a stand or arm, pivoted to the side frame about 9 inches below the centre of the rollers. On the bolt or pivot which carries these arms there is an eccentric sleeve, the arm being bored out to fit on this sleeve. Thus the roller may be not only moved to and from the other roller, but either end may be raised or lowered to bring the rollers exactly in line and parallel, by turning the eccentric sleeve at either end of the roller. To tell whether the rollers are exactly in line—and absolute alignment is positively necessary—the proof plate is employed. This

consists of a plate of iron trued perfectly plane upon one side, and stiffened by suitable ribs. If, in laying this upon the upper surface of the rollers, it rocks, the rolls are not in line, and it will be necessary to raise or lower one end of the movable roller of that pair. Alignment being secured, the rolls will granulate evenly throughout their entire length. To prevent the rollers from coming within a fixed distance, there is a strong spring back of each

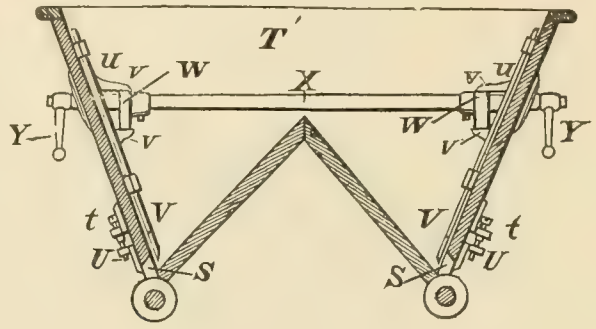


FIG. 289.—HOPPER OF GRAY'S ROLLER FRAME.

journal, through each of which there passes a bolt with check nuts. The springs can be set up to any distance apart by means of a hand-wheel and screw at each end.

To spread the four rolls apart when stopping or when starting the mill, and to bring them back to their original position, there are two eccentrics

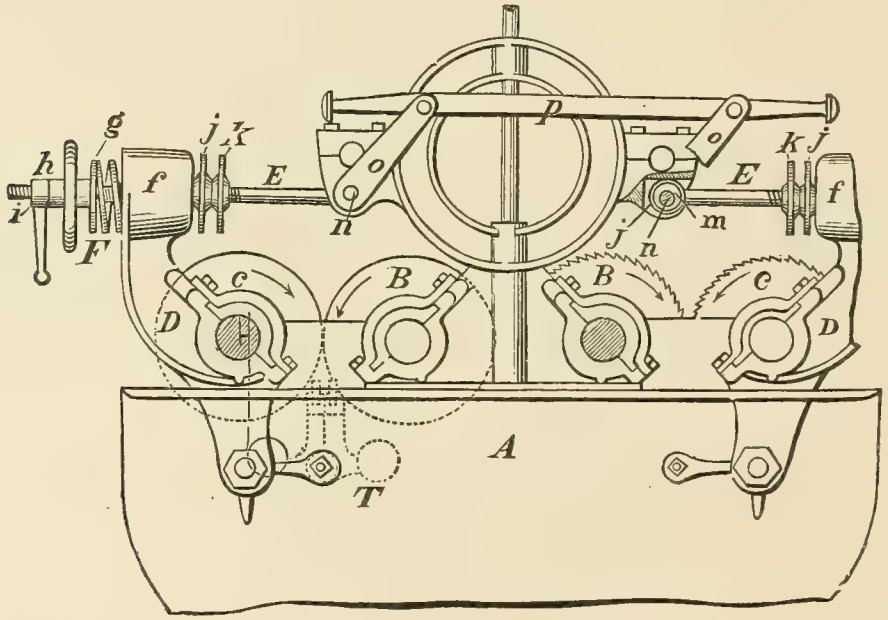


FIG. 290.—SPREADING DEVICE AND ADJUSTMENTS.

with a throw-out handle on the side of the frame. This is to prevent the belt from slipping by reason of stuff accumulated between the rolls, when the machine starts up. There is a handle upon the hopper, Fig. 289, connected to gates inside of the hopper, which are to shut off the feed at any

minute, without touching or altering the adjustment of the feed-roll gates, intended for minute adjustment, and being located on the outside of the hopper.

Fig. 290 shows the spreading device and the adjustments of the rolls and bearings.

The following directions for using are furnished by the makers with each machine :

First. Clean the rolls ; turn the check nut back on the pull-rod toward the centre of the machine ; make the roll just touch its mate, by means of the hand-wheel. Lay the proof plates, sent with the machine, on the bodies of one pair of rolls. If you can "rock" the plate, then the rolls are not parallel. Loosen the screw through eccentric a little, and turn the eccentric carefully with the wrench until the plate cannot be rocked. Now fasten the screw well, and the rolls are in working order. The rolls must be tried with the proof plate every four weeks.

Second. Press the rolls together by means of the hand-wheel about as much as needed, bearing in mind that a great amount of power is lost by unnecessary pressure, and screw back the check-nuts against the swing-box, opening the rolls as much as desired. If both ends of the roll are evenly apart, as can be ascertained by a piece of paper, tin, etc., then screw against the first check-nut the second one, therewith locking the first one.

Third. When stopping the whole mill, push or pull on the throw-out handle connecting the throw-out cranks, thereby opening both pairs of rolls, without disturbing the hand-wheel; this is to allow no leak from the feed-gate to lodge between the rolls when idle and cause the running off of driving belt after mill is started again.

Fourth. To insure a positive motion, the belts on the back must be tightened ; this can be done while the machine is running. Loosen the set-screw in the sleeve, and screw down the centre by means of the socket wrench sent with the machine. The main belt can be tightened in the same manner. Tighten the set-screw again.

Fifth. Keep the oil trough clean. Clean out the drip-pipe by entering the wire cleaner furnished, entering it in the little hole in circular molding, etc.

Sixth. By turning rolls end for end, machine can be made left-handed in a few minutes. (Corrugated rolls, however, do not admit reversing.) Keep the bearings well lubricated, using the best oil and no tallow. Fill the cups with cotton wicking, and enter same in oil holes, so as to touch shafts. The self-oiling boxes of all ten bearings will work well and keep bearings cool, if properly cleaned and kept in order. There are oil drains below bearings, carrying the waste oil back to centre of box. These drains must be cleaned once in six to eight weeks. Take out the rolls and remove the little hard wood plugs on inside and outside face of box below shaft, enter a wire in drain-hole, drive in the plug again and put back the rolls, and the boxes will remain cool ; keep the leather packing between cap and bottom of boxes oil-tight, laying in paper packing, if required, to stop leaks.

CHAPTER XXXIII.

MIDDLINGS MACHINES.

Middlings Machines—Middlings Milling by Burrs—Middlings Purifiers—Principle of the Purifier—Grading Middlings—Kinds of Middlings—Dusting Middlings—Keeping the Cloths Clean—Collecting and Grading Flour Dust—The G. T. Smith Purifier—Middlings Returns—Clothing—Number and Size of Purifiers—General Remarks on Purifiers—Grinding Unpurified Middlings—Bran Cleaning.

Middlings Machines.—The main object of modern milling being the production and subsequent purification and reduction of middlings, we may properly consider as of special importance to those machines, which have for their object the handling and treatment of that material.

We may divide them into those effecting grading, dusting, purification and reduction, with incidental reference in this connection to dust catchers and middlings reels.

The various machines and processes for producing middlings, having been considered in detail, in their appropriate special chapters, we shall say but little on that head, other than to give a general introduction to this subject of middlings milling, as distinct from the other operations of flat or low milling, bolting, bran cleaning, etc.

We must, however, spare time to lay special stress upon the fact that, the most successful modern milling is middlings milling, a term covering broadly, the intentional production of as large a proportion as possible of middlings, which are to be afterward floured, after being purified from the discoloring and innutritious matter formerly irremovable.

Such an object and its attainment by any "system," "process," or combination thereof, constitutes modern milling. The principal methods of accomplishing the desired end are many and various. Shading almost imperceptibly into each other, by reason of the "combination" and "compromise" systems introduced more frequently, than pure and simple processes of any one type.

There is, then, high burr milling, in which the middlings are produced on stones, at one operation; high burr milling, in which they are made in several breaks, by stones, each break followed by proper "scalping," or separation of the products. By means of cast-iron discs, middlings making may be effected, either at one or in several operations; and single rolls working against a breast, and roll pairs working together, each may be employed to produce middlings, either in one pass or in several. The general result is the same—an output of middlings, ready to be treated independently of other products, as the source of the best grades of flour, all other operations and products being subordinate.

The various compromises, combinations and complications which ensue preclude any satisfactory general treatment of the subject, and equally for-

bid a disquisition on any one of them, which shall be complete without a reference to the others, and even without a repetition of much matter belonging equally under other heads.

We must, then, while advising our readers to consider no one chapter of this work as complete, and to consult the others, especially in connection with the very copious index, apologize for what may seem, without such premise, needless repetition.

Middlings Milling by Burrs.—In this connection the chapter on millstone dresses may be consulted with advantage, as well as that especially devoted to middlings purification.

The following paragraphs have been contributed by Mr. J. D. Nolan :

" In the first place, the burrs should be so arranged, dressed and run as to make the largest possible percentage of middlings, and they should be of as even a grade as possible. This is necessary, as it is too troublesome and difficult to purify uneven middlings. Then the grinding of middlings is somewhat difficult also. The stones must not be too large—not over three feet ; they should be carefully and evenly dressed, and the furrows in the bed-stone should be shallow—not over one-eighth inch at the skirt. They should also be wide, with very little land. Middlings do not need much land, because there is no bran to clean, and, besides, they are much more easily pulverized than the wheat, having lost the protecting influence of the bran. Grain can stand rough handling because it has the bran to protect it, and it is the bran that wears and glazes the stone ; but the middlings, if roughly handled, stand an excellent chance of being killed before they reach the periphery of the stone as flour. Besides this, if middlings are ground with wheat they are apt to absorb whatever essential oil may escape from the berries ground with them under the stone. Middlings being very tender require careful handling ; they should be graded also, and each grade should be ground on a separate stone. Great care must be taken that the spindle does not get out of tram, that the stone is not in wind, and that both furrows and lands are smoothly dressed. A good, heavy stone of small diameter is considered the best, and to have this the stone should be backed up with scrap iron instead of burr-block spawls.

" It sometimes happens that a miller who desires to bring up the grade of the flour from the first grinding often adds from one-fourth to one-half of the reground first middlings. This gives color and strength. Where no purifier is used, it is best to grind the middlings close, with a pretty heavy feed, in which case it would be well to use half as many runs on middlings as on wheat. Where a purifier is used, in a seven-run mill, there should be at least three run on middlings, and they should be the sharpest and most even in texture and temper. In some cases it is necessary to run the burrs slowly in grinding middlings in order to grind fast, but it often happens that in slow grinding the middlings stop in the eye, and in this case it is necessary to use some means of forcing the middlings under the burrs. Many use a rod of wood placed inside of the eye and extending to the balance rynd. The rotary motion imparted to the rod by the revolving stone is said to prevent choking.

"The No. 1 middlings contain the best part of the berry, and from them the highest patent should be made. Although it may not slick up as white as that from the No. 2, it will dough up whiter and stronger. For No. 1 middlings the rolls should not be set very close, and the reel should be medium fine, say one-half No. 11 and the other No. 12, except about eighteen inches of No. 1 at the tail. Wheat that will not pass through a finer cloth may be sent to a purifier clothed with about equal lengths of Nos. 8, 5 and 3, with six inches of No. 0 on the tail end. This will take out the bran and some light, fluffy stuff that looks white but does up blue and without strength, being mostly cellulose. After purifying this material it may be sent to another set of rolls and reduced, and then bolted on a reel clothed with No. 12 or 13, and eighteen inches of No. 1. What passes through the No. 1 may be finished upon biscuit rolls or burrs, making a fair second patent by using cloth a little finer than that of the next preceding reel. The No. 2 middlings may be crushed heavier, as they contain less germ, and are finer anyhow. They may be bolted on a reel clothed with equal lengths of Nos. 12, 13 and 14, and about eighteen inches of No. 1 at the tail. The material coming through the No. 1 may be worked up with the material of the No. 1 middlings, on porcelain rolls or on burrs. The No. 3 middlings may be treated about the same as the No. 2, but the reels will be about one number finer, the tailings being reduced for bakers' flour."

An experienced miller says: "For middlings, the furrows should be large, flat, and have a very smooth feather-edge, say three-fourths furrow surface and one-fourth land. Furrows and lands should be as smooth as possible. Old stock stones not too open make the best granulation. New stock is inclined to make soft and flat middlings.

"One reason why the middlings should never be run back to the eye of the stone in grinding wheat is that, if the burrs are dressed for granulating wheat, they cannot possibly grind middlings. In fact, a good miller will always dress his stones with a view to the particular kind of work they have to do. Besides this, the grains of wheat and particles of middlings are so different in size, that, when the stone is set at the proper height to granulate wheat, the middlings pass through without being properly acted upon, and when the stones are close enough to granulate, or rather 'reduce' middlings the wheat is neither granulated nor ground, and this is almost tantamount to low grinding, which is not at all desirable in making middlings."

Some millers claim that stones which are run too fast will make soft middlings, which will be likely to be full of the germ and of a "red-dog" appearance. If there is too much land surface and not enough draft, the middlings will have the same appearance.

The advocates of "new process" burr milling say, as against the roller system, that middlings require to be ground and not crushed, as crushing makes a dead flour which cannot be made lively, and produces a dead, unpalatable and unwholesome bread, and one earnest opponent of rolls (an interested champion of burrs, by the way), says: "An ordinary pair of millstones will do as much as four sets of rollers, and with less power. Rollers will often flatten the bran so that it will not appear in the flour, but will be

seen in the bread. One reason why rollers were introduced into Hungary was that their millstones were inferior to the French."

Middlings should be round, sharp and of as nearly one size as possible. Flour made from small shrunken wheat must be poorer than that from sound well-matured berries, and mixing them makes flour lower than the average of the two. It would be well to grade before sending to the smutter or brush.

In trying to make all the middlings possible, remember that there is a danger that they may be made in bad shape, and of all different sizes, perhaps from No. 9 to No. ooo, and this will give trouble, especially in a small mill, where there is no means of grading. Middlings, from No. 1 to No. ooo, cannot be purified in that condition, because they are liable to have particles of the bran sticking to them, instead of simply being mixed therewith. Another reason is that the germ or chit, which is of the same size and weight as fine middlings, is generally found with them, and cannot be taken out by either air or silk.

Middlings Purifiers.—Before purifiers employing both a sieving and an air separation came in there was great loss in the manufacture of high-grade flour, as it was impossible to clean the coarse bran, and, of course, all the gluten that adhered to it was lost. Then, again, when the middlings were reground, the bran dust could not be got out, and they bolted through into the flour. Then the specks and dust entered into the flour.

It is the office of the purifier to remove all of the fine bran which is in the middlings before the latter are reground.

The purifier is now necessary in either large or small mills working either old or new process. It is the only machine which will clean the flour from finely-divided particles of bran as fine as the flour itself, and from the fuzzy material that adheres to the wheat. Bolting will not take these out. There is as yet in general use nothing but a uniform, constant current of air that will do it, and this answers because they are much lighter than the middlings.

There are few cases where the purifier should not be introduced. Of course there are such instances, and they are referred to under the head of grinding unpurified middlings; but the use of the purifier is nowadays generally considered as essential as the employment of cleaning machinery to scour the berries and brush out the crease dirt.

The Principle of the Purifier.—The function of the purifier being to effect two separations, by size and by weight, giving three classes of products, this is effected in most of the machines in this country by air currents which remove the lighter portions (principally composed of fine bran particles), while sieves of special bolting silk remove, in suitable grades, the clean, hard, heavy middlings, allowing the germ middlings and coarse, heavy impurities to "tail over" for subsequent repurification, or for such disposition as may seem the most advantageous.

In Europe other principles are employed, as, for instance, so-called "centrifugal force," combined with air currents; and in this country frictional electricity is proposed as a substitute for the air currents, for the separation by weight.

Grading Middlings.—If it is essential that whole wheat berries shall be graded according to size before being "ended" between ending stones, and desirable that such grading should precede gradual reduction, where the capacity of the mill warrants it, it is equally advantageous to give a purifier, which has two classes of work to perform, material as uniform as is possible, that the sieves and air currents may be arranged for some special size and weight, and be given that and nothing else.

Middlings should be graded when first-class work is desired.

There are many cases where purifiers are given uneven middlings to work upon, and are then blamed for not doing good work. When middlings are even in size they can be better acted upon by both the screens and the air currents. Here is where the advantage of grading the middlings before purification comes in. Sometimes they are so uneven that there are some of them too large to go through the meshes of any part of the silk screen.

Grading is desirable in almost every case. The number of grades depends upon the quantity of middlings. In some cases it is not economy to grade too far.

Where the improved American sieve purifiers are used it is not economy to make more than three or four grades of middlings. In the smaller mills two grades are sufficient.

A good way to grade middlings is by reels, each grade being sent by itself to a purifier clothed with a cloth one number finer than the reel from which it came.

Kinds of Middlings.—There is need of having some settled nomenclature for millers' use. The various words middlings, shorts, sharps, grits, groats, semolina, and all the rest, are used indiscriminately, so it is hard to tell where one leaves off and the other begins. Why not use the word "middlings," and define it as meaning all the flour-producing part of the wheat that has not been reduced to flour-dust by passing it through any reduction machine? They may be subdivided into fine midds, or those that will pass through a No. 10 cloth and over a No. 14; medium midds, or those that will pass through a No. 6 and over a No. 10; and coarse midds, or those that will pass over a No. 6 cloth and through a cloth coarser than a No. 6. The word middlings has but one meaning to the American miller, while shorts may mean pure, fine bran, or it may mean middlings; the same with sharps. Grits, groats and semolina are imported words, and are used to designate certain sizes of middlings.

As regards the terms "coarse," "medium" and "fine" middlings, Mr. Littlejohn defines, as his understanding of coarse middlings, those that will pass through from No. 1 to No. 3 cloth; medium, those from 4 to 7 inclusive; and fine, those that will pass through from No. 7 to No. 10 inclusive. All above No. 10 is flour and not middlings. Much patent flour is made on No. 9 cloth. Middlings that pass through No. 9 or 10 cloth need no purification. R. C. Brown considers all middlings that will pass through No. 1 cloth as No. 1 middlings, those that will go through No. 2 cloth as No. 2 middlings, which is a very sensible suggestion.

The easiest middlings to purify are round uniform middlings, thoroughly free from flour dust, without any reference to the grade of wheat of which they are made.

Low grinding produces middlings that are more difficult to treat than those from high grinding.

Most purifiers can treat coarse middlings from hard wheat and high grinding ; but those from soft wheat and low grinding are more difficult, as fine middlings are apt to be carried over into the dust-room.

Soft returns from rolls, tailings and finished middlings are hard to purify.

The most difficult middlings to handle are made from Fultz wheat (soft winter).

The softer the middlings the greater the number of purifiers they require to bring them up to the same state of purification.

It is common to get fine middlings that will pass through No. 9 or No. 10 cloth, and these are generally sent to be ground without purifying.

Middlings that will pass through a No. 9 or No. 10 cloth, or even a No. 12, No. 13 or No. 14, can be purified as well and as economically as coarser, providing they are properly graded, and the cloth on the purifier and the air currents are adjusted to suit the work.

Middlings that will pass through a No. 11 silk will not get into the stive-room if they are put into a purifier that is properly clothed and the air currents properly adjusted.

The fibre in middlings is often so fine as to be made known only by the red shade.

Dusting Middlings.—Before purifying, the middlings should be well dusted, not only to save the fine flour which might otherwise be carried away with the offal, but to increase the capacity of the purifier and lessen, as far as possible, the wear of the silk resulting from the constant use of silk-cleaning devices. As a matter of course, if the middlings are covered and intermingled with fine flouring particles, and are run in this condition on to the head of the purifier, if the air current be at all strong the nutritious dust will be carried over with the offal into the stive-room or the dust catcher. If, to prevent this, the air current be too light, then the fine flour dust will get through the silk and with it a certain proportion of that reddish material which it is the special object of the purifier to remove.

For dusting, a reel may be used clothed according to judgment, the clothing having a definite relation to that of the purifier itself.

Most mills lack dusting capacity for their middlings. The flour removed from the bran by the bran-duster is of an inferior quality, so much so that many millers do not care to save it because, though it is so white, it is lifeless, and deteriorates the flour with which it is mixed. No miller would like any incorporated with his patent flour. Now, this same dead flour also adheres to the middlings. It is claimed that by the action of the disintegrator it is removed, and where the dusting reel is used it is saved. This material should be saved to be treated in any desired manner. If you ask a miller whether he wants his bran-duster flour in his patent flour he will promptly

say No. Yet that same miller will some time object at first to removing this dead flour.

There are cases where the miller complains that his purifier is not working well, when really it is his own fault for not supplying the machine with properly prepared material.

The dust from the middlings purifier is one of the most annoying and dangerous things about a mill; and it is not only annoying and dangerous, but with the present system of drawing the air-supply of the purifier from the air within the mill, the lower surfaces of the cloth become clogged, necessitating the use of a brush or other cleaning device. It has been proposed to remedy this annoyance and expense by giving the purifier air from outside, uncontaminated with fine particles; but this would only be a partial remedy.

The use of a dusting-reel is advantageous, as by this means much of the flour is taken out before the middlings go to the purifier, thus lessening the amount of flour that is blown into the dust-room.

Thorough dusting of the middlings is absolutely necessary. Middlings cannot be economically purified, in fact, cannot be thoroughly purified, if there is any quantity of soft flour dust remaining when they go to the purifier. It may not be necessary in all cases to use a reel that is distinctively a dusting-reel ; but a thorough separation must be made of the flour from the middlings before the latter go on to the purifier. This can only be done where the grinding has been well done, and a thorough system of bolting adopted.

Keeping the Cloths Clean.—As most purifiers are arranged, there is a constant source of trouble in the clogging of the silk screens from two causes—first, the actual wedging, in the meshes, of particles of middlings; and second, the covering of the under surface with fine floury dust, carried and held up against the cloth by means of the upward air current. If this air current be warm and moist, the trouble is aggravated. It is worse where the silk is of a poor grade than where the meshes are uniform in size and regular in shape, and free from fuzz and gum.

A purifier without some means of keeping the cloth clean is simply worthless. If the meshes of the cloth are not kept perfectly free from dust rich material will run over with the tailings.

The finer the grade of silk employed, the greater the necessity of keeping it open. With a coarse cloth the purification depends too much upon the air-drafts, and the assistance of the cloth is in a great measure lost. The most common device employed is an automatic traveling brush.

The life of the cloth of a middlings purifier having a traveling brush is stated at one and a half to two years. Something depends upon the kind of material, the care with which the machines are operated, and the quality of the brush used.

If the meshes of the cloth are not kept open good material will go over the tail and into the dust-room, and the middlings that are sifted through the cloth will be imperfectly purified.

The under side of the cloth is clogged with dust that comes from the middlings and from the air about the mill. No matter how thoroughly the mid-

dlings are dusted or freed from flour, there is enough dust in the air about the mill to clog up the meshes. This might, perhaps, be largely obviated by drawing the suction of the machine from the air without the mill. The dust could not be entirely overcome by drawing the air from without the mill, because some dust will follow the middlings through the cloth, and this cannot be avoided, because flour dust is being constantly made by the action of the middlings upon themselves, that is, they are being constantly reduced by handling.

Collecting and Grading Flour Dust.—Fig. 291 shows a mode of collecting and grading dust of flour and grain, and also the dust from the

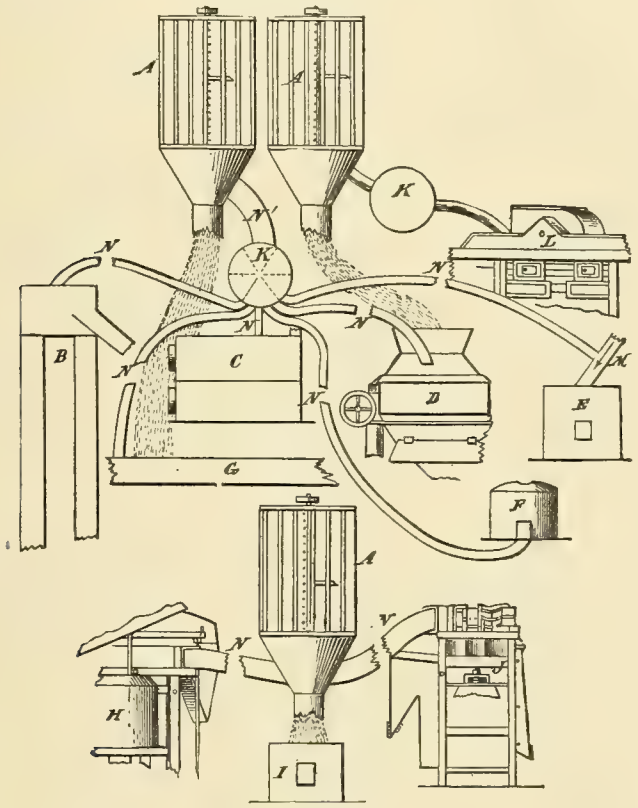


FIG. 291.

middlings purifier. There is a balloon or balloons, A, for straining dust from currents of air drawn from a plant of milling machinery. The dust is blown into the balloons through the cloth-covered sides, the air escaping back into the mill. There is a hopper bottom to the balloon to receive the strained-off dust, which can be spouted off to where it is desired. Unless the machines on which such a balloon operates have these appliances for creating strong air currents there may be one or more fan-blowers, K, combined with the balloon and connected by air-trunk, N, to the machine, and by another trunk, N′, to the balloon. In Fig. 291 the elevator bolting chest B, crushing rollers C, stock-bin E, spout M, to stock-bin millstones F, conveyors G, are all supposed to yield substantially the same grade of flour dust, which is returned from the balloon to the conveyors G. The flour dust from the middlings purifier L is also supposed to be of substantially the same grade, and is there-

fore returned to the crushing rollers C. The smut mill H and the brush machine J are supposed to yield the same grade of grain dust, which is therefore returned to a receptacle, I, connected with the balloon bearing on both the smutter and brush machine. The warm air from the machines and appliances can be returned into the mill to avoid any drafts of cold air.

The dust catcher, if of proper construction, has the merit of assisting in keeping the mill temperature warm in winter, by reason of drawing the supply of air for the purifiers from within the mill, instead of from out of doors. This, of course, assists the bolting and saves fuel.

It saves the expense and space of long ponderous dust spouts, gives the purifiers free vent, deposits the various grades of dust separately, and indicates at any time what each purifier is blowing out.

The G. T. Smith Purifier* (Fig. 292).—One of the most important combinations included in the G. T. Smith machines are those covered by United States patents Nos. 208,936 and 236,101, of which the elements are a shaker clothed with graded cloths, running from the finest at the head to the coarsest at the tail, and feed mechanism for supplying the middlings in a thin stream distributed equally across the entire width of the cloth; a casing which, taking the air below the shaker, forms a trunk, carrying it through the entire extent of the cloth and above it and away through the fan outlet, a dust chamber being formed in the air passage, in which dust raised by the passage of the air through the middlings on the screen is deposited.

In the drawings of the patents, the dust-room is formed in the case; but the claims are not limited to any special position, as this is manifestly not essential.

So, also, the intensity of the air currents through different parts of the screw, as illustrated, and controlled by slides, which enable the miller to let on more or less air opposite any section of cloth; and claims are made, covering combinations, in which such means for regulating the current are elements. As, however, the natural result of passing a column of air in motion through a screen of successively coarser cloths, sifting middlings as they run down the cloth, will be that the least current shall pass at the head, where not only the cloth is of finest mesh, but the material on the cloth is of greatest depth, and that the force of the air current will increase as the meshes grow more open, and the material is thinner and coarser.

It is claimed to follow that, even without the valves, the material, growing coarser, will be subject to air currents of increasing force. Therefore, claim is made to this organization of the graded shaker, the fan and the case forming an air-trunk, not only to direct the air to the screen, but to control the outgoing air, so as to make it deposit in the chamber the dust with which it is laden.

The effect of the graded cloth is to grade the middlings and deliver them in the hopper of different sizes. Sometimes it is desirable to keep them separate, sometimes to mingle them before grinding. The means for doing

*Made by the Geo. T. Smith Middlings Purifier Co., of Jackson, Mich.

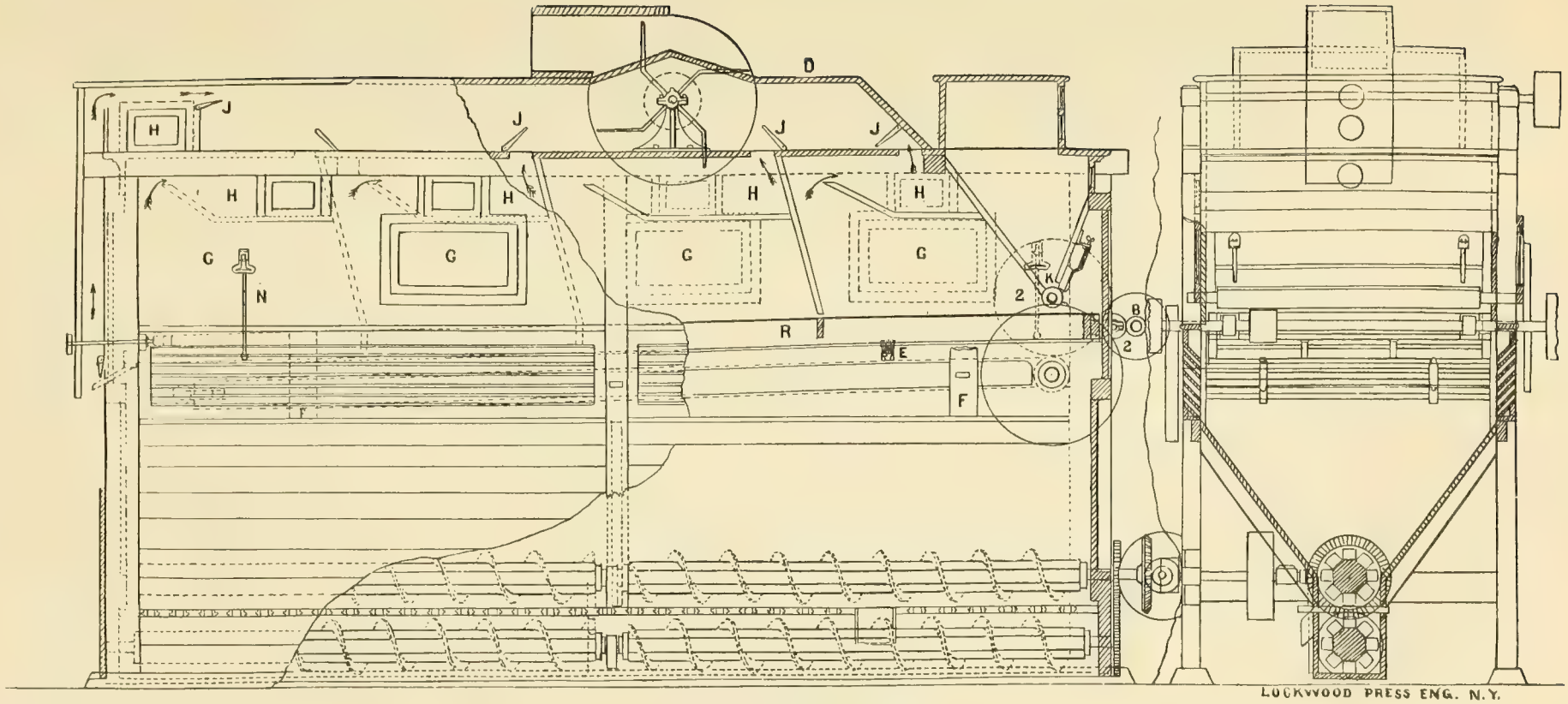


FIG. 292.—SECTIONAL VIEW OF GEO. T. SMITH PURIFIER.

this are provided in a conveyor and series of slides, which are made elements in combination, covered by No. 236,101.

In working purifiers, it was found that fibrous matter gathered on the cloth underneath that so effectually closed the meshes that in a little time the screen became inoperative. Brushes are used on the under side of the cloth (this is covered by the patent No. 164,050) to relieve the meshes from adhering particles.

In order to enable the miller to know what is going on in his machines, provision is made for pockets to catch the escaping dust and permit its inspection. This feature is covered by re-issued patent to G. T. and Aaron Smith, No. 6,197.

When the machines were applied in large mills it was found inconvenient to treat all grades of middlings on one machine, and experience soon taught the necessity of grading middlings by passing them over a separate reel, and sending different grades to purifiers specially adapted to each grade. This combination is the subject of patent No. 158,992.

The shakers, as illustrated in the patent, were placed side by side in the same casing; but it is held that the use of independent machines, placed to receive and treat the different amounts coming from the section of the separator, is the mere adoption of an equivalent.

The machines first introduced into the Washburn Mill were applied to the ordinary system of low grinding, in which the middlings were a mere residuum remaining after the larger product of flour had been taken out. It was soon concluded that the use of purifiers required a change in the mode of milling, and accordingly there was introduced what soon became known as "new process milling."

Bearing on this there was a patent, No. 137,945, the claim of which briefly defines the peculiarities of new process milling as "manufacturing flour from middlings by subjecting them to successive grindings, boltings and intermediate purification by currents of air." Whether this is really a new process, or an old one revived by the aid of improved appliances, is a question that has never yet been adjudicated. While the grinding recommended is somewhat higher than that ordinarily practised, it is believed to be essentially different from the high-milling system of European mills, in which the breaks were into large fragments of grain and flour only as a final result.

The latest improvement on this machine to facilitate putting on cloths, tightening them and changing them is as follows: Strips of wood, $\frac{3}{4}$ of an inch by $1\frac{1}{2}$ inches, are placed at the lower edge, and on the inside of the frame of the shaker. Three-eighth-inch bolts, having thumb-nuts, secure these strips to the shaker frame. The bolts are of sufficient length to allow the strips to be drawn half an inch away from and toward the centre of the shaker. Directly over these strips are other strips, 1 inch by $1\frac{1}{8}$ inches, and screwed fast to the shaker frame. The first-mentioned strips are also bolted to the last-mentioned, a slot being made in the last strip to permit the lower strip to be moved horizontally without removing the bolts. The lower strips are first moved toward the centre of the shaker, say half an inch, then the cloth is tacked to the lower edge, and tacked in the usual way across the end at the

tail. At the head it is tacked to strips the same as it is at the sides. When the cloth becomes loose, or rather slack by being stretched, it can be made taut again by simply turning up the thumb-nuts on the bolts, such action drawing the strips out toward the sides of the shaker. The cloth can be stretched endways by turning the nuts on the bolts which carry the strips across the head of the shaker. Cloth that is well stretched on at first will in time stretch about three-quarters of an inch, so that if we allow half an inch play for the strip on each, all the possible requirements are provided for. No matter how taut the cloth may be drawn when it is first put on, it will in a short time require to be taken up, or rather drawn tight again. The best results can only be obtained when the cloth is drawn tight, as with only such a condition will the middlings flow in a steady and uniform stream down the cloth. In many cases where makers have been called to adjust machines that were not working satisfactorily, they had found the cause of the trouble to be the cloth had not been drawn tight when put on, or it had become slack by stretching through use. When the cloth has been drawn tight, by turning the nuts on the bolts which hold the lower strips to the shaker, then the lower strip is drawn up to the upper one by turning the nuts on the bolts that pass through both strips. This upper strip being fast to the side of the shaker, holds the lower one in a horizontal line. When it is desirable to change the cloth, the nuts on the cloth, the nuts on the bolts through the side of the shaker are removed, and the strips, with the cloth still attached, can be removed from the machine. These strips can be removed from the machine and made fast in any convenient place, care being taken to place them just the right distance apart, and the cloth can be tacked to them, at the same time stretching it; then the strips can be taken up, and the cloth and strips rolled together and put back into the machine through the side and under the shaker, and the strips placed in position on the shaker. After tacking its ends, the cloth can be stretched as before described. If it becomes necessary, the cloth can be stretched while the machine is in operation, and in a very short time.

GUARANTEED CAPACITY OF G. T. SMITH'S MIDDLINGS PURIFIER.

No.	Sq. Ft. Cloth.	Run of Burrs.	Bushels of Wheat per hour.*	Price.
00 Single.	17	1	6	$225
2 "	32	2	12	400
4 "	47	3	16	500
6 "	55	4	20	600
1 Double.	30	2		400
2 "	36	2		450
3 "	44	3		500

Soft middlings require a longer shake than round sharp ones. The proper length of stroke for either soft or round middlings is the one

* The column of bushels of wheat per hour is for medium grinding, neither very high nor very close, but as high as is economical without grinding the bran.

that will keep the mass moving at the proper speed down the cloth and which agitates the middlings the least. The length of stroke is governed by the speed of the eccentric. For instance, an eccentric having a throw of five-sixteenths of an inch must have a speed of 500 revolutions, while an eccentric having a throw of three-eighths of an inch must have a speed of 450.

The strength of the current should be so regulated as to keep the middlings just a little elevated above the surface of the screen. It should be strong enough to carry off the lightest impurities and float the heavier ones over the tail. The middlings should never be much lifted from the screen. It is absolutely necessary that the current shall be of equal intensity on all portions of the cloth at any one place in its length, and that the middlings be equally distributed over the cloth, lest the air current seek the bare places and carry off more than impurities from those places while doing no cleaning in the crowded places.

The head of the Smith machine produces the best middlings. "The best middlings are those that are the most thoroughly purified. The reason is, the vibration of the shaker carries the impurities to the top of the mass, the pure middlings going to the bottom next the cloth, and are sifted through the cloth toward the head of the shaker. As the mass passes down the sieve the quantity of pure middlings is constantly lessened, and the impurities reaching the cloth are sifted through with those that are too heavy to be wafted away by the air currents. It is at the point that where the heavy impurities begin to sift through that the operator should cut off and return to the head of the machine. By cutting off and returning the heavier material the load at the tail is increased and the heavy impurities carried farther and farther down the sieve each time they are returned until they are at last forced over the tail, where it is desirable they should be sent.

Middlings Returns.—Because the wheat berry is composed of different kinds of material in different proportions, and because the various kernals which are being ground differ in texture and condition, there are in the meal, as it comes from the burrs, several grades of flour and several of bran. The white flour-producing portion next the skin, or bran containing more gluten than the other portions, is firmer and tougher than the starchy portion in the centre. By reason of this the ordinary process of grinding and bolting produces four different grades of material.

The meal, after leaving the stone, is conveyed to the reel-bolt or series of bolts (sometimes after being passed through an intermediate cooler or hopper-boy; but this is not necessary, nor does it effect the number or quantity of the different grades); what passes through the head of the reel, clothed say with No. 10 cloth, forms a merchantable grade of flour without further manipulation, being sent directly to the packer. The next product of the reel-bolt, the returns, are frequently fine enough for high grade of flour, sometimes, indeed, passing through the No. 10 cloth, like the merchantable flour, but, containing a large quantity of fine bran and other specks, they cannot be put with the flour directly, lest they discolor it and lower its value. These portions cannot be reground, because they are already fine enough;

so they are taken back to the freshly ground chop, mixed with this last, and then rebolted with the same set of reels. This takes the specks out and increases the yield.

The next product, the middlings, or mixture of fine bran, cockle specks, and other foreign substances, fuzzy fibrous materials, which have been separated from the skin of the berry, and the coarse grains of that part of the kernal which lies next the skin, contains so much gluten that, although the particles must have been acted upon longer than the starchy centre of the berry, they retain their angular form. After purifying them in a machine having a draft of air, and then regrinding and bolting, a part of the result is mixed with the flour taken from the head of the reel, and the rest is sold separately as low grade, because all of the middlings were ground at once, and all made fine in order to detach the bran, rendering the product difficult or almost impossible to bolt. In order to get flour from middlings, in which the granules are larger and more uniform in size than the flour made from the centre or starchy portion of the berry, and in order to have this product free from the fine dust-like particles produced by fine grinding, there has been devised by G. T. Smith a process (which he has protected to himself by letters patent) of purifying, grinding and bolting the middlings, and automatically returning the middlings returns to be again purified, ground and bolted.

By this system, under ordinary circumstances, the wheat is ground upon stones dressed in the usual manner, and having say thirty-two cracks to the inch; grinding high enough to make about 30 to 45 per cent. of middlings. The chop is bolted through an ordinary reel bolt, and the merchantable flour packed as a first grade. The middlings are elevated to the purifier, and, after purification, are re-ground upon a middlings stone with a perfectly true face and draft, and having clean regular sharp cracks. Instead of grinding all of the material at one operation to the desired grade of fineness, the middlings, meal or chop, are taken to the reel clothed with No. 10, having such capacity that it shall be constantly overloaded, so that about one-third of what is fed in shall tail over. This will prevent the specks passing through. The middlings returns are not fine enough for flour; but a small proportion of flour will carry the specks over the tail. These middlings returns are taken to the purifier, the head of which is clothed with No. 10. This is intended to let the finer flour fall through, but to take out the specks and fine bran.

The purified flour is put with that from the reel-bolt, or else mixed with the middlings meal before this is sent to the reel. The tail end of the middlings purifier is clothed with a coarser cloth to let the larger granules of returns fall through. That which falls through being free from specks, is sent to the middlings stone and reground with the middlings which come from the first-mentioned purifier. Few of the middlings returns which are taken from the middlings reel are as coarse as the middlings which are treated upon the first purifier. Hence it is not desirable to use as coarse cloth or as strong draft with the shaker upon which the middlings returns are purified, because a strong draft would draw away the finer portions; but a coarse

cloth at the tail would let the bran through, and thus prevent sending coarse returns to the stone direct. It is better to put No. 7 upon the tail of the returns purifier, and to send the tailings of this purifier to the first purifier, the tail of which should be clothed with No. 4, to prevent anything going over except the offal.

If it is not possible to have a seconds or returns purifier, the returns are sent to the middlings purifier, so that the flour will be there purified and fall through the No. 10 at the head.

The force of the blast should be least on the mass while it contains much fine middlings and flour. Hence there will be waste from excessive dust-room deposits. To avoid this the middlings should be thoroughly dusted.

In early machines, either there was only a single grade of cloth on the shaker, or, where graded cloths were used, there was no extension of the trunk above the shaker, so that the fine stuff lifted by the air was wasted, and, by filling the air with its inflammable particles, produced liability to explosions such as that which destroyed the Washburn Mill in Minneapolis, where the latter class of machines was employed.

Those middlings that will pass through a No. 4 or over a No. 8 cloth require considerable cleaning, there generally being more fine bran and specks than in the other grades except the germ middlings. As they are finer than the germ or the No. 1 middlings, as strong an air current cannot be used with them. They should first be well dusted and then run through three purifiers in succession, the first clothed with equal lengths of Nos. 7, 5, 3 and 1, and six inches of No. 00 at the tail.

It must be noted that middlings will not pass through the same number of cloth on a purifier that they will on a reel, because the air resists their tendency to pass through. Thus those that pass through this machine go to the next. Those that tail over go to the red-dog stone or to the shorts bin. The next machine may have more fine cloth at the head. If the middlings that pass through the cloth near the head are clean, they may go to the rolls, and those going through the coarser cloths may be sent to the next machine, which may be clothed with two-thirds of No. 5 and one-third of No. 0. These middlings should be sent with those from the other machine to the smooth rolls (which should be set up very close), and the material then sent to a reel of the fancy chest, clothed with Nos. 12 and 13. This flour should be a good patent, and the tailings can be worked up well with those from other reels having the same kind of stock, either upon biscuit (porcelain, so-called) rolls or between burrs. In all cases middlings should be thoroughly dusted before going to the purifier, to prevent the air current from carrying away the fine flour dust. Of course, if the middlings are gummy, which is often the case with fine winter wheat middlings where the grinding is done very close, the inner coating of the bran is pulverized with the middlings and the heat produced by the friction will glutenize the fine middlings so that no process of purification will separate the specks from the pure fine particles of middlings. This is apt to take place under the roller process on winter wheat.

In reply to the question, What is the best way to purify germ middlings?

it might be answered, That purifiers are better than aspirators, because, although they cost more, the quality of the work is much better.

Purifiers for germ middlings should be clothed with equal lengths of Nos. oo, ooo and oooo, the latter at the tail. The tailings from this machine should be sent to the shorts bin, although they may be sent to the low-grade stone to be ground into red-dog.

Those middlings that pass through the cloth should be sent to the smooth germ rolls; the other middlings may be graded into about three different grades, and each be purified upon a separate system. The No. 1 should pass through a No. 0 and over a No. 4; the No. 2 should pass through No. 4 and over No. 8; the No. 3 should pass through No. 8 and over No. 10 or 11. Having them thus graded gives the miller chance to use either light or heavy suction on the purifiers. The No. 3 middlings should pass through three machines in succession. The first of these machines should be clothed with equal lengths of Nos. 5, 4, 2, 0 and 00; the No. 5 being at the head, what passes over the tail of this machine should be sent to a set of tailings rolls; the middlings passing through the cloth should be sent to the next purifier to be recleaned. This lower machine should be clothed with equal lengths of Nos. 4, 2, 1 and 00. What passes through this machine should go to another clothed with Nos. 4, 3, 2, 1 and 00. Those that pass through the head of this last machine should go to the smooth rolls. Those that pass through near the tail can be returned to the head of the first machine. By this means, if the feed gets low, it may be kept up and the machine be kept properly loaded.

Clothing.—The cloth on a purifier must be graded according to the quantity of the material which is to be operated upon and its quality. No general principle or rule can be laid down for the clothing of purifiers, unless it may be that the cloth placed at the head must be fine enough, so that very little of the finest material will pass through, and graded coarser toward the tail, so that nearly all of the middlings will pass through the cloth, and nothing be left to be passed over the tail excepting the light material which is held up by the air currents and floated over. There is no difference in clothing for spring or winter wheat. In either case the quantity and condition of the middlings are taken into consideration in making up the cloth. There is little if any difference in the capacity of a purifier for handling spring or winter wheat middlings, quantity and condition being the same. Spring wheat middlings are harder and sharper than those from winter wheat, and are, therefore, as a rule, made freer of flour and flour dust before they go on to the purifier. The more thoroughly the middlings are dusted the greater will be the capacity of the purifier.

There is no difference in the plan of clothing for custom and merchant milling; in either case the clothing will depend entirely upon the quantity, quality and condition of the middlings. We mean by quality of the middlings their size and shape. If from high grinding, with the stone in proper condition, the middlings will be large, sharp and round; with the stone out of condition, in close grinding, they will be soft and flat. By condition we mean whether graded, and whether free from flour or not.

There need be no difference in clothing for old and new process milling, excepting in the fineness of the cloth, and that is governed, as before, by the quantity, quality and condition of the middlings.

If there is any difference in middlings necessitating a difference in clothing the purifier, it will perhaps be found that middlings from soft winter wheat are the most difficult to clean, being generally more flat and requiring closer cloth and more air.

If winter wheat middlings are more flat than spring, it is because imperfect stones have been used in the grinding, or the grinding has been imperfectly done, in which case they would require coarser cloth and less air than if they were sharp and round. The flat middlings are more easily lifted and carried to the dust-room than sharp, round ones. The head of the purifier should be clothed with cloth one grade finer than the reel, and the tail should be clothed with cloth one to three numbers coarser than the cloth on the reel.

Some mill furnishers say that in grading purifier cloth they are guided by the size of the middlings, regardless of the quality, whether from winter or spring wheat.

A milling paper says: "For high grinding of spring wheat the purifier may be clothed at the head with from No. 6 to No. oo at the tail." If the middlings have first been graded on a No. 6 cloth, then the clothing described would be proper for a machine to handle the coarse middlings, the finer middlings being treated on a machine separately; but if the whole of the middlings are to be sent to the one machine, finer cloth should be used at the head, say No. 10 and grade down to No. oo.

The popular belief that spring wheat middlings purify more easily than winter has doubtless grown out of the fact that the same care in grinding has not been taken by the winter wheat millers. Of course if the middlings are made flatter through poor grinding of the wheat, coarser cloth is required.

One miller makes no difference between clothing for winter or spring wheat middlings. The same miller uses coarser cloth for new process work, as the material is coarser.

One miller thinks that for winter wheat middlings the purifier should have from one to two numbers coarse cloth, and lighter air supply than for spring and for rye middlings, less air supply and coarser cloth than for winter wheat middlings. He gives one number coarser cloth for custom than for merchant mills, and the same air supply. He thinks that several small machines are better than fewer large ones of the same joint capacity, because a heavy weight of middlings will lie "loggy" and not allow perfect permeation with air.

One authority thinks that rye middlings, being soft like those from winter wheat, require about the same treatment. He says that clothing and air supply are the same under either process—that is, you must be guided by the size of the middlings as to fineness of cloth, and have air supply sufficient to carry off impurities, but no stock. He also thinks that what is good for a merchant mill is good for a custom mill, and says that when more than one hundred pounds of middlings are made per hour it is best to divide them into one or more grades, to be treated on machines by themselves, always

taking the seconds of the finer machine and breaking them again with the middlings next coarser. By seconds are meant the middlings obtained toward the tail-end of the shaker, which are not well enough purified to be reground, and are returned when only one machine is used.

In clothing purifiers for the Jones process, of course the manner of clothing depends upon the middlings to be handled, but, as a general rule, it may be stated that for the fine Nos. 10, 8, 7, 6 and 4 should be used, and for the others Nos. 8, 6, 4, 2 1 and 0. If a scalping purifier is used, it should have Nos. 6, 4, 2 and 00.

Number and Size of Purifiers.—The number and size of machines should be proportioned to the quality and quantity of work to be done. In remodeling old mills, reference must always be had to the room and space available in which to place the machines. For instance, if one were running a 300-barrel mill, and making two grades of middlings, the larger machines should be used, and fewer of them than if greater number of grades were made of the same quantity of middlings.

The size of the machine should be in proportion to the work it has to do. The disadvantage of a machine too large can be overcome by clothing finer, while a machine that is too small is always too small.

The larger the machine the finer the cloth and the longer the middlings can be retained on the sieve, permitting a more gentle application of the air current.

Those who prefer a large machine say that they do so because they think the large machine gives better chance for the light to raise on top.

The employment of few large machines instead of more small ones of the same joint capacity necessitates less attention, less spouting and elevators, and less room. Large machines of some makes are not as good as the smaller sizes, as the feeding devices are poor, so that sometimes a large part of the cloth is bare.

Instead of buying one large purifier for three run of stones, many millers think it better to get two small ones, because they can better regulate the air-drafts.

One correspondent recommends small machines. It is impossible to handle middlings in large quantities and do good work. It is better for the same material to go through two or more machines, no matter how good the purifiers are.

The small purifiers are not only easier to handle, but perhaps more durable.

General Remarks on Purifiers.—The use of middlings burrs and purifiers can be made profitable in custom mills if the system of exchange is adopted.

The question is sometimes asked: If roller mills are better than stone mills, why are there so many more purifiers needed? The answer is, That more purifiers are needed because there are more middlings to handle, not because there is more bran and dirt among the middlings.

In changing from stones to rolls, the same purifiers may be employed, but there will be less draught needed. Sometimes, where there is a new mill

started, there will be back pressure upon the purifier from the stive-room, and thus, instead of there being less air-draft needed, there will be more required.

The disadvantages of the disintegrator are that the bran remains loaded with flour and the flour is not of good color. In order to effect this process the wheat must be either naturally or artificially dampened. On the other hand, when looking for a system to handle damp wheats or those that have become artificially dampened, the disintegrator lends its aid.

Middlings should be handled as carefully as possible to avoid breaking them up, and for this reason there should not be too much crank movement.

There is a great analogy between bolting middlings without purification and grinding wheat without cleaning. To get three grades of middlings, employ three numbers of cloth, as Nos. 6, 3 and 1, in the order named. To dust middlings, pass through a reel clothed with No. 13. Each grade of middlings should be ground on a separate stone. To effect this, it is well that the purifiers should be over the stock-hoppers, each grade having a separate hopper.

The perfectly even distribution of the middlings over the entire width of the cloth is of the highest importance, as, if there are bare or thin places, not only will the distribution of air be affected, but the capacity of the machine will be lessened.

The coarser the middlings the more air is needed.

The more screen surface a purifier has the more perfect and the less wasteful its work.

As a rule it is not best to return material to bolts for machines through which it has been returned, except to help along the feed, or where there is too much bolting surface.

If middlings flour is made from dry wheat it will carry all over the world.

In ordering a purifier, send a sample of the middlings to be sent to the machine, and say how many bushels of wheat will be ground per hour, or the number of pounds of middlings made per hour, and if the cut-off will be returned to the machine or otherwise disposed of.

Grinding Unpurified Middlings.—Of course there are mills where the introduction of the purifier has not been effected; and even some where it might not be policy to put in one—as, for instance, in a new country, where there is no opposition mill, and no special demand for fine grades of flour. In such a case, the object of the miller would simply be, with the smallest outlay of capital and the least skilled labor, to produce from fairly cleaned wheat, a marketable "straight" flour. Yet it may be desirable to flour the middlings separately. In this connection an old miller says:

"To get the most and best flour from middlings without the purifier, they must be ground close and warm with a heavy feed, and with the burrs making 225 revolutions. This should give 24 pounds of good flour from 40 pounds of middlings."

Bran Cleaning.—This operation, also known as "bran dusting" and "bran dressing," was, in the days of low milling by burrs, effected between

ERRATUM.

PAGE 424.—By an inadvertence, the chapter on Bran Cleaning has been run up into that on Purification.

stones specially dressed and run therefor, and which after a fashion removed from the inner side of the already well rubbed bran flake some of the adhering glutenous flour and even fine middlings, adding to the white and valuable material thus removed, a quota of pulverized reddish fibre, ground off from the bran flakes. The advent of high burr milling—in which the endeavor to produce a large percentage of middlings free from bran flakes rendered the obtaining of clean bran impossible from the very nature of high burr milling—made bran dressing a more important factor than before, in the economy of the mill.

As a supplement to the bran stones, which at best could not be given such a perfectly smooth dress and such perfect balance as the nature of the task really demanded—came the rotary brush cleaners, wire gauze cylinders, through which is forced the material removed from the flakes, by the rapidly revolving cylindrical brush. These machines effected a considerable saving over and above that by the stones.

The use of chilled iron roll pairs with spiral corrugations and highly differential speed to effect bran cleaning, either as a continuance of "gradual reduction" or wheat breaks by rolls, or to follow any kind of milling which produces bran-bearing rich material, is highly satisfactory.

A fourth class of bran-cleaning devices more distinctively employed for that purpose comprises machines having two or more rotating concentric cylindrical cages, armed with rods or pins parallel with the axis, these being generally arranged in inkles, those in one cage alternately with those in the other, and the distance between them being very slight. The bran flakes being continuously fed in at the eye or axial centre of the machine (which is kept full of material), or by friction among themselves and on the pins and the walls of the rotating cages, almost entirely denuded of the flour and middlings which may adhere to the valueless flakes ; while, if the operation is properly conducted, comparatively little innutritious and discoloring substance is broken off.

Many people have an idea that the bran is about as tough as india-rubber, and can be rolled off the wheat as though it were a regular peel. This is not the case, however. It requires careful handling, not only in the earlier stages of its separate existence, but down to the last moment when it is put into the dresser to have its adhering flour and middlings removed.

That thorough bran dressing is desirable is no longer a question. It is to be regretted that some look at it rather as a way of thoroughly dressing the bran, than as a means of increasing the profitable yield.

Lawton & Arndt's Bran Dresser.—This consists essentially of two cast-iron discs or heads rotating in opposite directions on a horizontal axis, each bearing on its inner face concentric circles of cylindrical steel pins projecting about two and a half inches, and spaced wider on the inner circles than on the outer. The circles of pins in the two heads interlock alternately. The bran to be cleaned is fed in centrally by means of a screw conveyor running through the hollow shaft of one of the rotating "cages."

The material in its passage outward is thoroughly whipped by the circles of pins passing in opposite directions. The journals are usually long, and the

bearings adjustable vertically to take up any wear of the brasses, and, also, laterally to put the discs in tram, so as to keep the circles perfectly concentric and the pins accurately parallel. Each of the oppositely rotating discs having a speed of 600 rotations* per minute, the machine has a whipping action due a speed of 1200, and with only one-half the wear on the journals and brasses, while it is probable that the bran particles are more thoroughly turned over and over in their outward passage.

Guaranteed Economy of Bran Dressers.—Millers are often unreasonable in demanding of manufacturers guarantees of performance or economy, when the conditions are not only unknown to the maker of the machine or the introducer of the process, but are absolutely not even get-at-able, or perhaps vary greatly from day to day. They consider, in the case of a bran-dressing machine, that the maker should guarantee the bran to

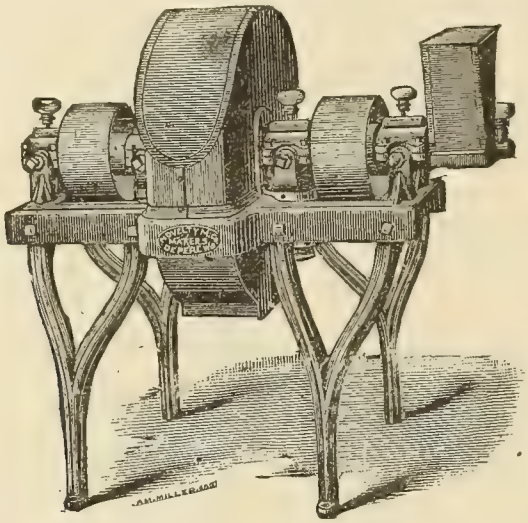


FIG. 293—LAWTON & ARNDT'S BRAN DRESSER.†

"lay up" below a certain maximum. The machine builders are naturally unwilling to guarantee any particular weight of bran as the product of their machines, for the reason that it is a poor proof of the manner in which it has been cleaned. Then there is a vast difference in the bran from different kinds of wheat; that is, the fibrous woody portion of the bran is much thicker on some varieties of wheat than on others. A bran consisting of large unbroken pieces containing a considerable per cent. of valuable material may "lay up" light and bulky, and to such a test weighs very light to the bushel; while another sample, perfectly clean, broken up or ground down fine, may lay close and compact and weigh heavy. So the best test to put the bran to, is probably to *inspect it and see if there is anything on it.*

What any bran-dressing machine can do depends upon the desire of the operator, as it does with a millstone. If run *rapidly* enough it will clean the bran thoroughly, but is apt to injure the result by making too much fine dirt or dust, while to run it at a more moderate feed results in better stock, but the bran will not be so well cleaned.

* The expression, "revolutions per minute," might as well be corrected here as anywhere else. "Rotations" is the correct word for spinning on an axis—The earth "rotates" on its axis, and "revolves" around the sun.

† Made by Lawton & Arndt, Depere, Wis.

CHAPTER XXXIV.

BOLTING.

Bolting—Methods Employed—Bolting Cloths—Wire Cloths—Silk and Wire Bolting Cloths Compared—Mending Cloths—Cleaning Cloths—Putting on the Cloth—Sliding of the Chop—Speed of the Reels—Capacity of Reels—Care of the Bolts—Keeping the Cloth Clean—Reels—Bolting Chests—Speck Box—Improved Bolting Chest—Screw Bolt Feeder—Rules for Clothing—To Get out Middlings—Clothing for Single Reel—Three Reels—Six Reel Chest—Scalping—Dusting Reel—Custom Work—Altering Reels—Reels in the Hungarian System—Wire Clothed Reels—The Centrifugal Machine—Wheat Meal Purification—Rebolting—Bolting for Custom Mills—Hints.

Bolting.—The objects of bolting are easily stated—grading, separation, and purification. Reels are used to separate products of one kind, but of various sizes, as fine and coarse middlings; to separate one or more different products irrespective of their value (as middlings and flour), and to take out impure material, which would discolor the product, as bran from flour. As the term is generally applied, it means the separation of the various components of Graham or chop, viz., flour, middlings, and bran.

Bran, besides darkening flour by its presence, produces fermentation, makes sugar and gum in the bread, and gives it a dark color.

Methods Employed.—Bolting is generally done on slowly rotating hexagonal reels, slightly inclined, and covered with special silk cloth, having meshes of extraordinary regularity of form and size. There are used, however, cylindrical and conical reels; and woolen cloth and wire gauze are used instead of silk. In addition to this, recent practice has witnessed the introduction of rapidly turning reels provided with internal brushes; and also, stationary inclined sieves, against which the chop is thrown by a rapidly rotating drum.

Bolting Cloths.—In the manufacture of silk bolting cloths, which has within the past few years received such an impetus, great care must be taken in the selection of raw material and in every stage of manufacture.

The raw material is bought in the markets of Lyons, the finest and longest fibres being selected. Constant supervision must be exercised in every stage of the process.

The fibre is spun and re-spun, as there must be no knots or loose fibres. The finished bolting cloth must be heavy and strong; the meshes perfectly even in size and regular in shape. Sizing must be avoided, as this rots the silk and clogs the meshes. The thread must be heavy and round.

It is evident that the more fibres there are per square inch of the fabric, the more the manufacture costs; but this cost is not relatively proportional to the number of fibres, for it costs proportionately very much more to put in a great number of fibres than only a few.

The fabric will be seen under the microscope to be different from ordinary gauzes, in that, instead of the warp or chain going simply over and under the

filling, it is twisted in every mesh, not only to give strength to the fabric, but to prevent the fibres of the filling from moving out of place, and hence altering the shape and size of the meshes.

Figure 294 shows how the fibres should be. Fig. 295 has only one half of the fibres in one direction twisted, while in Fig. 296 there is no twisting at all.

The reason why very much more care must be taken in the manufacture of bolting cloth than the finest grades of silk for wearing apparel is, that while in the latter case it is the *fabric* which is sold, and the meshes should properly be invisible, in the former case it is the *meshes* (or holes) which are the object of manufacture, and the purchaser desires to buy them as fine, regular and even as possible. The tighter the fibres are twisted, the harder and rounder they will be, the less fuzz they will present, the more regular the interstices will be, and the longer the cloth will last.

On what is known as "extra heavy" there is the same number of meshes per square inch as in the regular numbers; but the orifices are proportionately smaller, by reason of the stouter fibres employed. Under the microscope the

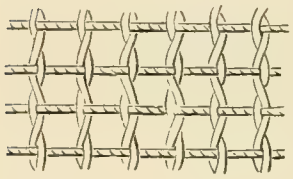


FIG. 294.—GOOD.

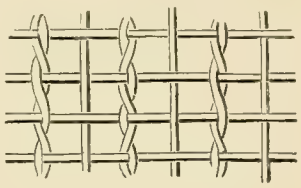


FIG. 295.—IMITATION.

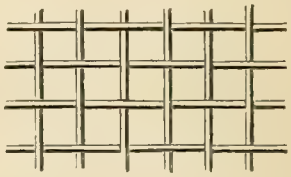


FIG. 296.—VERY POOR.

meshes should not appear oblong or hexagonal, but almost perfectly square. Appended is a table showing the number of meshes per square inch of various numbers of Dufour & Co.'s Old Anker cloth: *

DUFOUR & CO.'S BOLTING CLOTH.

No. of Meshes to the English Square Inch.

No.		No.	
0000 contains	324	9 contains	8836
000 "	484	10 "	11236
00 "	784	11 "	12996
0 "	1444	12 "	15376
1 "	2304	13 "	16900
2 "	2704	14 "	19321
3 "	3136	15 "	21904
4 "	3600	16 "	24336
5 "	4096	17 "	26569
6 "	5184	18 "	27869
7 "	6400	19 "	28900
8 "	7056	20 "	29929

Bolting silk is said to be adulterated with mohair.

Cheap cloths are often found to be at least one number coarser than they purport to be.

Some dealers take a light quality of cloth and represent it as a standard number of good cloth, having a better cloth, the extra numbers of which

* R. P. Charles, New York.

they call extra heavy, and a third brand, all numbers of which they call double extra heavy, when in fact they have only the standard numbers of three different brands of cloth, and not three qualities of the same brand.

In comparing two brands of cloth we find sometimes that one brand will have more meshes than the other in the finer brands, while in the coarser numbers it will be the other way.

The stone is often blamed for the fault of the bolt.

A small quantity of gum is undoubtedly required to keep the silk fibre from coming in contact with the middlings. To test whether the silk cloth has size in it wash and rub it.

Wire Cloths.—Wire cloth is also used for bolting, and is preferred by some. It is carefully woven on looms built expressly for the purpose, and it is graded according to the fineness of the wire used in its manufacture. A very good article of wire cloth (Fig. 297) is manufactured by the Brooklyn Wire Cloth Works.*

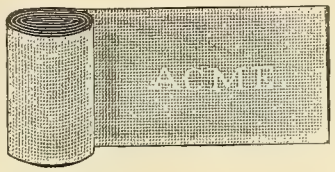


FIG. 297.—WIRE BOLTING CLOTH.

Silk and Wire Bolting Cloths Compared.—The following table shows the comparative size of meshes of wire cloth and silk bolting cloth:

TABLE SHOWING COMPARATIVE SIZE OF MESHES OF WIRE CLOTH AND SILK BOLTING CLOTH.

No.	18	Mesh	Wire	Cloth	equals	No.	0000	Silk	Bolting	Cloth,	324 meshes to the inch.
"	22	"	"	"	"		000	"	"		484 " "
"	28	"	"	"	"		00	"	"		784 " "
"	30	"	"	"	"		0	"	"		1,444 " "
"	36	"	"	"	"		1	"	"		2,304 " "
"	50	"	"	"	"		2	"	"		2,704 " "
"	54	"	"	"	"		3	"	"		3,136 " "
"	60	"	"	"	"		4	"	"		3,600 " "
"	64	"	"	"	"		5	"	"		4,096 " "
"	70	"	"	about	"	"	6	"	"		5,184 " "
"	80	"	"	"	"	"	7	"	"		6,400 " "
"	90	"	"	about	"	"	8	"	"		7,056 " "
"	100	"	"	"	"	"	9	"	"		8,836 " "
"	110	"	"	"	"	"	10	"	"		11,236 " "
"	120	"	"	"	"	"	11	"	"		12,996 " "
"	125	"	"	"	"	"	12	"	"		15,376 " "
"	130	"	"	"	"	"	13	"	"		16,900 " "
"	150	"	"	about	"	"	14	"	"		19,321 " "

Mending Cloths.—Once in a while some peddler comes about with a bottle of fancy cement for mending bolting cloth, and which is in reality nothing but a good solution of isinglass. When we say isinglass we mean

* F. G. Richardson, 107 John Street, New York.

that material prepared from fish sounds, and not mica used by stove makers and often miscalled isinglass. Isinglass court-plaster is neat and handy, and mends bolting cloths well.

Cleaning Cloths.—In some mills we find the cloths carefully cleaned, and in others this operation is never performed, partly because it is not the habit to do so, partly because no one about the mill knows how, and perhaps because the cloth is not good enough to stand it. There is much talk about the use of a brush. Some say that it is absolutely necessary, and always will be so; others say that its use is only a temporary custom, and that something better will turn up, or the necessity for using it will be done away with.

Putting on the Cloth.—"As bolting silk is generally about forty inches wide, it would be as well to make the reel so that two widths would cover it. Reels for custom mills ought to be 85 to 90 inches, so that, with the addition of ticking or webbing, the cloth would just cover."

Some advocate putting cloth on the inside of the ribs, cutting the cloth in strips just wide enough to reach from rib to rib, and having the ticking strong enough to hold the tacks. The cloth must be tacked on the head of the reel and even with the inside of the rib, and then the strips stretched endwise as tight as possible and tacked on. Cloth must always be evenly stretched, else the meshes are distorted and made to clog easier.

As to the question whether the speed of bolting reels should be increased or diminished when the cloth is put upon the inside of the ribs, some think that it should be increased considerably; because, if run at a low speed, the chop slides around in a compact mass, and no air is admitted into it.

"The finer portions are the heaviest and fall through first, next the head. If there is too much bolting surface, and the flour is specked, the cloth may be put inside of one rib and outside of the other, so that the flour will slip over every other rib without being lifted. This will make the reel bolt clear."

Sliding of the Chop.—At what angle will chop slide? Watch one section of the reel through one-quarter revolution; that is, from the flat position to a perpendicular. At 45° to 50° chop will slide, although that is not steep enough for a spout. At 75° to 80° bolting cloth may be used for the under side of a spout, without any flour coming through; while at 50° to 55° all will come through that can get through.

Speed of the Reels.—How many who read this could, without counting, say how many revolutions per minute his reels are making?

Fast speed of the reels is a greater disadvantage than slow, because, instead of increasing the bolting capacity and quantity, the centrifugal force simply prevents the material from sliding along over the surface, and it is carried up and around and drops.

Some say that 300 feet per minute is the maximum speed for a point on the circumference of a reel.

Capacity of Reels.—The question of how full a reel ought to be to do the best work is best judged by watching each reel and seeing under what condition of fullness it does its best work. In a water-mill the air is colder and damper than in a steam mill. Bolting capacity is less. Good grinding, that is, even grinding, permits the use of coarser bolting cloths. English

millers generally use too little bolting surface; Hungarians and perhaps Americans go to the other extreme.

Care of the Bolts.—In many mills too little care is taken with the bolts. They are supposed to be infallible, and to need no more care. There are millers who will take all possible care of their burrs, but who will never think of taking the slightest precaution with their chests.

Chests should not be allowed to stand idle and partly open in cold weather, nor where they can be subjected either to direct spray or to dampness. If the reel by any means gets damp, it may be remedied by circulation of air.

One of the greatest nuisances about a mill is a little insect, the scientific name of which we will not attempt to give, for two reasons: First, we do not think it is important, and second, we do not know it. The main question is, what will prevent or destroy this nuisance? It deposits its eggs in the interstices between ribs and silk, and in cracks of the chest, and cuts the cloth.

Turpentine is recommended, as also are knockers.

Keeping the Cloth Clean.—It is said that a quart of dried peas placed in the bolting reel will increase the capacity and keep the cloth open. The peas are caught by a screen, turned into the elevator, and returned to the reel. Knockers have been tried very often, and while they fail to clear the bolts properly, most of them make specky flour. The best way for a miller to keep his cloths clear is to buy good silk to start with.

"How many men are there traveling about the country putting in patent knockers guaranteed to knock spots out of every other device made, invented or contrived, to knock the miller from the deep hole of poverty and hard work to the proud and lofty pinnacle of success and affluence? But if I wanted to make specky flour I would have knockers on both ends of every reel."

There are cases where the agents of patent knocking devices find a mill in which the bolts are making specked flour, and will apply one of the knockers, at the same time putting the stones in perfect face and balance. Of course, after this the flour will be clearer than before, and the agent of the patent knocker will claim and receive the benefit.

Reels.—"The head of the reel, it is thought by some, should be a large annular disc. In building the head-piece, have a pattern from which to make twelve cants of three-fourth inch pine lumber. Join these truly, then fasten one tier on the other, breaking joints in the middle, fastening with glue and $1\frac{3}{8}$-inch screws. The opening in the middle should be large enough to admit the reel shaft conveyor. The opening is covered by a thin circular lid, fitting closely around the conveyor.

"The head of the disc should be three inches larger in diameter than the outside of the ribs, so that if the head be turned when put upon the reel a groove can be cut in the middle of the edge to admit thin lining, which would greatly tend to make the inner parts of the chest speck-proof. Triangular ribs have at the base of the triangle a tangent that would cut the cloth half an inch above, if stretched on the reel, or the chord of an arc of a circle whose radius is the line from the centre of the reel to the outside ribs. The angle opposite the ribs is 30°.

"A reel 37½ inches in diameter clothes to advantage, because the meal, making a turn on the ribs, generally passes over a portion of the cloth without any bolting operation taking effect upon that strip of the cloth, whereas when the angle formed by the rib is more filled up and rounded off by the extra width of rib and of ticking, all the surface of the cloth is used in bolting. The tail-piece can be made of three thicknesses of cants nailed together, the inner circle being about two inches smaller than the outer, so as to form a groove for admitting lining boards.

"One authority prefers to put the cloth on light bars or sashes, with triangular cross-bars at proper intervals, with points or ends notched back and put on with screws. The cloth is stretched on this bar, at the inside ends of the apex of the triangular cross-bar, but clear of it. The sash is screwed down on to the ribs of the reel, instead of the bars coming flush with their edges, which should be slightly rounded. The ticking is tight between the bar and the rib, and there is no room for vermin to lodge."

Bolting Chests.—Each reel should have at least two conveyors (three are better) and an unlimited number of cut-offs. If there be several chests, and the flour is to be mixed, this can be done by a conveyor running at right angles to those under the reels. Each reel should be so arranged as to be inspected its entire length and at both ends at any time by opening the doors, which should be double, the outside doors being close and tight, and the inner ones covered with muslin for ventilation. The reel shafts should be glued up from pieces of thoroughly seasoned wood, making them firm and durable, and preventing all tendency to spring. The reels of conveyors should be all driven from the head of the chest, and the reels should be so arranged at the tail that they can be raised or lowered to any desired pitch by simply turning the screw. Each reel should be provided with double partitions, or false heads, forming speck boxes, which will prevent specks from getting into the flour. The chop should be admitted to the reels through an outside feed box, and should be deposited in the reel by a short conveyor on the reel shaft. The conveyors should all be made to project about ten inches at each end of the chest, and all spouts should be placed outside. They should be detachable and held in place by buttons, and each be provided with a covered hand hole, to enable the miller to make an examination of his stuff at any point. Each conveyor should be arranged as to be open to inspection its entire length without the use of sliding doors or glass, and as we have said before, be provided with an unlimited number of cut-offs. All reels and conveyors should be driven from the head of the chest by upright shafts, the conveyors being driven by combined spur and mitre gears.

If possible, the shafts should run in some sort of step by which the entire working parts of the bolt can be stopped and started at once by simply making a half turn with a wrench on a spindle. All chests should be provided with collars supported by neat iron brackets for convenience in examining the upper reels. By driving everything from the head of the chest torsional strain upon the upper conveyor may be avoided, this last being the prolific source of warping. This also enables the miller to have continual and instantaneous control of his chest. The ends of the chest should be detachable,

permitting the removal of the reel entire. Spouts should be large, and have plenty of pitch, and be polished inside to prevent clogging. It is best that reel conveyors should have the same number of revolutions as the reel over them, so that they can be run by the same gearing.

Ordinary patent knockers will do very well perhaps where there is very hot grinding and very little bolting capacity, but white flour must not be expected. There is no use in building reels to give a sliding motion to the chop

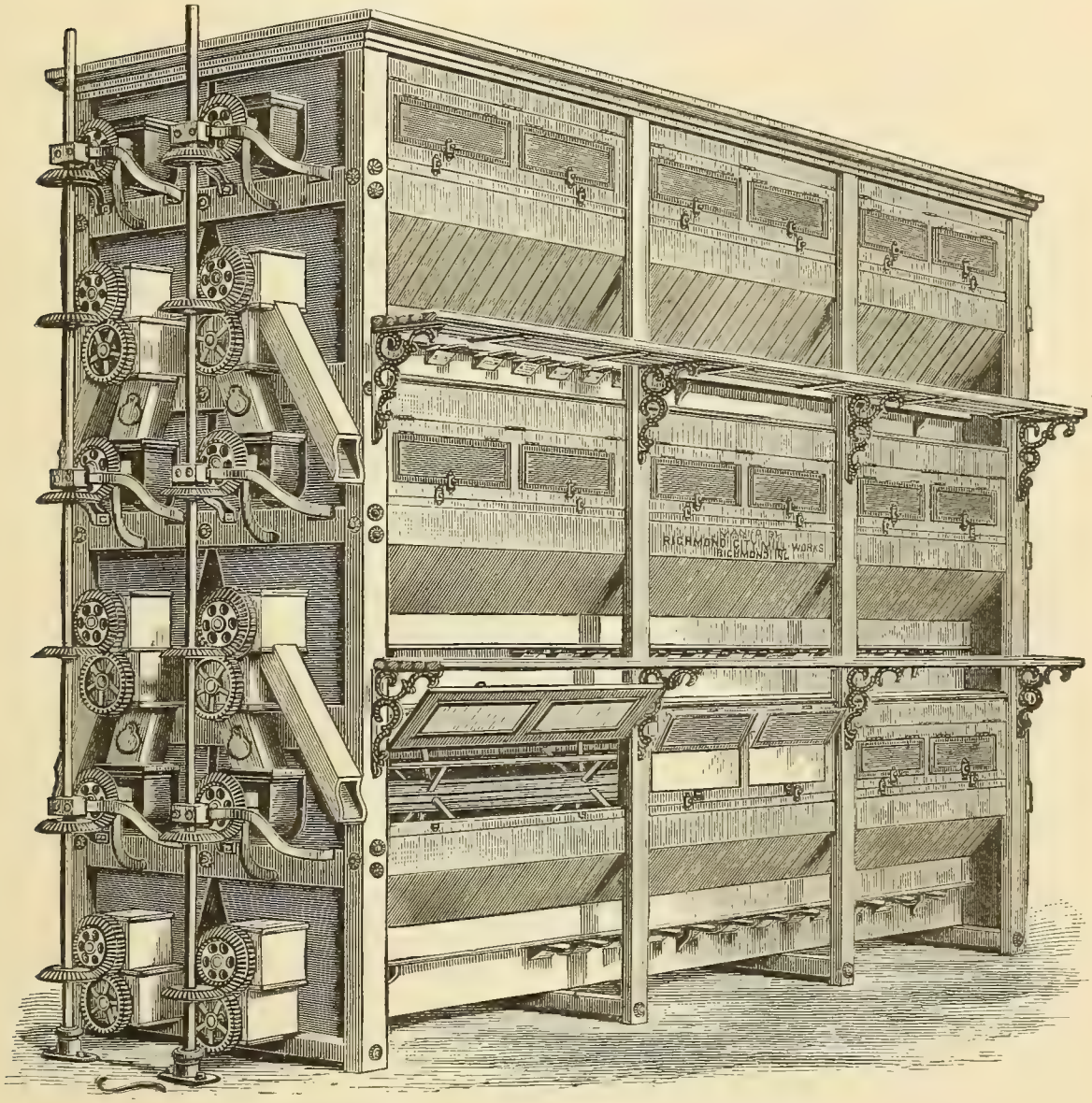


FIG. 298.—IMPROVED BOLTING CHEST.—RICHMOND CITY MILL WORKS.

in order to prevent it from falling against the cloth, and then to pay a man to put a machine on for the express purpose of jarring the specks through.

Speck Box.—The speck box is intended to prevent the specking of the flour from fine light stuff being carried up by the reel, and dusting through the opening in the reel.

To prevent dusting of flour out of the heads of reels, make an inner par-

tition across the chest, a few inches in beyond the head of the reel, about as high as the centre of the shaft, and having a semicircle cut out for the shaft to revolve in. This forms the inner side of the dusting trap or hopper, of which the outer boarding is the outside. Between the two are inclined end boards, converging nearly together at the bottom of the hopper. There is also trouble from dusting back into the flour of the dirt from the tailings. In merchant bolts sometimes part of the head and tail are cut off and returned.

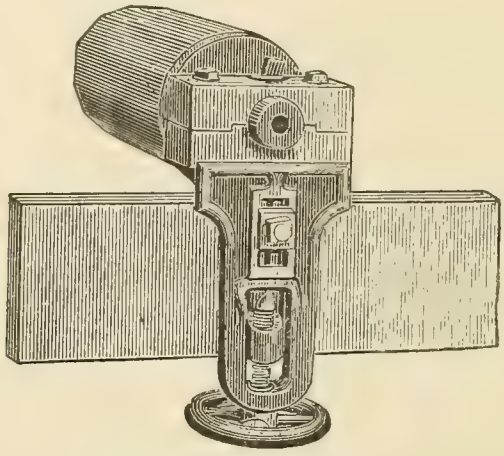


FIG. 299.—REEL-JACK.

Improved Bolting Chest.—In Fig. 298 is given an illustration of an improved bolting chest for new process merchant mills. This chest may consist of any number of reels, each reel having two conveyors, with an unlimited number of cut-offs. It is constructed in strict accordance with the specifications in the paragraph above as to "Bolting Chests." The reel-

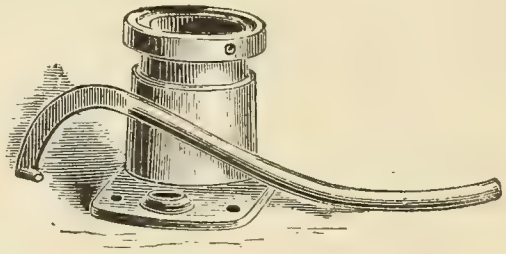


FIG. 300.—IMPROVED DROP-LIFT STEP.

jack, which raises or lowers the reels to any desired pitch, is shown in Fig. 299.

The uprights run in an improved "drop-lift" step—an ingenious contrivance by means of which the working parts of the bolt can be stopped or started in an instant by simply making a half turn with a wrench or spanner (Fig. 300). All chests are provided with galleries supported by neat iron brackets for convenience in examining the upper reels.

Among the points of superiority claimed for this chest may be mentioned: The compound arch brackets for supporting the upright shafts and head

gudgeons of the reels ; the combination of gears by which everything can be driven from the head of the chest, thus preventing all torsional strain on the upper conveyor (a prolific cause of warping), and enabling the miller to have a continual and instantaneous control of his chest ; the drop-lift step in connection with the above ; the reel-jack for raising and lowering the reels ; double doors for complete ventilation ; detachable ends permitting the removal of the reel entire ; improved slides for cut-offs, and increased pitch of slants and spouts, which are polished, preventing all clogging ; glued-up reel shafts ; well-proportioned and well-finished work throughout—only the most thoroughly seasoned and best materials being used.

These chests are manufactured exclusively by the Richmond City Mill Works, of Richmond, Indiana.

Screw Bolt Feeder.—Figures 301 and 302 show, in front and rear view, a device intended to be used wherever it is desirable to feed flour, mid-

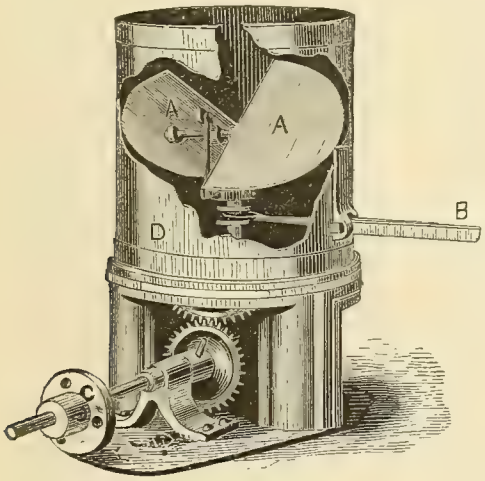


FIG. 301.—FRONT VIEW.

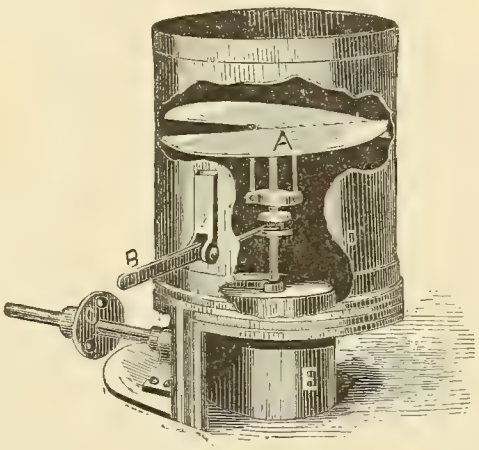


FIG. 302.—REAR VIEW.

SCREW BOLT FEEDER.

dlings or meal, with regularity, into the cooler, elevator or bolts. It is fastened to the head of the bolting chest, or in any convenient place, and driven by a pulley upon the shaft at C. A A are the flanges or leaves attached to the upright shaft, and revolve with it. B is the lever governing them. D is a cylindrical case made of galvanized iron, resting upon and fastened to the cast-iron frame. The frame is so constructed as to completely cover the gear wheels in front, and to allow a free passage of the flour or meal out at the back and around the base at E, while a sweep is attached to the shaft to prevent any lodgment on the upper part of the base. By raising or lowering the lever B, the feed will be increased or diminished as desired. This feeder will run either right or left, and should make about twenty-five or thirty revolutions per minute. The power required is exceedingly little, as will be readily seen, while an inch belt, or even less, is all that is necessary to run it. The height is twelve inches, and the diameter seven inches. The weight is about twenty-five pounds.

Rules for Clothing.—There seem to be more cast-iron rules laid down for millers than for any other class. There are plenty of these cast-iron rules

for reel clothing, and they are quoted and followed in all confidence without considering conditions. We find plenty of millers and mill furnishers prescribing a certain rule of clothing without the slightest knowledge whatever of the finer condition which should govern delicate devices of that kind.

The coarse cloth is put on at the head of the reel, because less bran there comes in contact with the cloth and there are fewer specks than at the tail. At the tail, the fine flour being sifted out, there is hardly anything to pass through but fine bran and fine shorts.

Brown recommends putting as coarse cloths as possible on the first superfine reels, getting clear flour, increasing in fineness toward the tail; putting a little finer on the second superfine reels, making all return to them. He says that if you must bolt middlings and flour in the same chest, do it in second reels; and says that middlings must be bolted separately. Middlings must not be dusted on too fine cloths, as the flour must be got out of them before going to the purifier.

There are many who put the coarse cloth at the tail of the superfine reels. They are wrong, because the reel, being more heavily loaded at the head, fewer specks come in contact with the cloth; and as these specks get more numerous in proportion to the mass, the cloth should be finest at the tail to prevent the specks from going through.

Brown thinks that most millers bolting winter wheat use too fine cloths, and cites one miller grinding Michigan wheat, who raised the price of his flour fifty cents per barrel by changing his cloths from No. 12 to No. 10, thus getting a better body for his flour.

The wheat is naturally hard and dry, and is passed through a heater. The meal from the wheat stone runs into a reel covered with No. 9 cloth. The reel has plenty of capacity, and has three feet of No. 2 at the tail, making the separation of the middlings from the bran also. The product from the No. 9 cloth goes to a reel covered with Nos. 10 XX and 11 X. After cutting off the flour from this reel, the remainder goes to the next reel, which is covered with Nos. 12 X and 13. Taking off flour from this reel also, the remainder goes back as returns, but is not returned to the meal or chop, but to the head of the second reel (clothed with Nos. 12 X and 13). The reason for this, as one familiar with bolting will see, is that returns made to a coarse cloth are liable to produce specks, as the material has just passed through a cloth two or three numbers finer than the cloth at the head of the first reel; and by returning to a fine cloth, or second flour reel, the liability is lessened, while, furthermore, you assist in keeping the second reel loaded better, so that both reels do a proportionate amount of work. The material passing over the end of the second flour reel should go to the dusting reel with the middlings from the No. 2 cloth on the tail end of the scalping reel. This dusting reel is covered with Nos. 12 X and 13. The product of this reel is also returned to the second flour reel, the middlings going over the end of the reel to the purifiers. The bran from the scalping reel goes to the bran duster. The reels of this chest are 16 feet long, 30 inches in diameter, and have two conveyors under each reel, except the scalping reel, which has but one. The dusting reel has two conveyors, because the middlings have to be

taken to the opposite side of the bolt, whence they are discharged to the purifiers. The middlings, after being ground, are run to a reel covered with Nos. 12 X and 13 cloth. After cutting off the flour, the remainder is run to another reel covered with twelve feet of No. 14 cloth at the head, and three feet of No. 10 cloth at the tail. Flour is also taken from this reel, and returns are made to its head. The product of the No. 10 cloth is carried to the head of the dusting reel in the other chest, as it contains some middlings, and as this practice has proved successful in one mill that the writer knows of, it is continued. We have been told by the proprietor that of three different kinds of purifiers the one he is now using is the only one that will treat this light material without waste; and that this fact is owing to its grading of the middlings, cloths and air to correspond, and its easy control and adjustability. He asserts that the purifier he is using easily pays for itself every thirty days by taking care of the tailings from the middlings. The reels in this last chest are 16 feet long also. It will be seen that this mill, with two run of stone, has six reels, and by the arrangement they have the proprietor can make a patent or straight grade as he chooses. His flour is bolted separately, is nicely dressed, and is each a different grade; but if he chooses to make a straight grade he has a conveyor that carries to one chest, and by feeding it into the flour from both reels in his wheat chest and both reels in his middlings chest the flour is well mixed and goes to one packer, making a superior grade of straight flour. This mill is making 25 per cent. of patent flour, using winter wheat, and until the last change in purifiers was obliged to make five barrels of low grade flour to the hundred, owing to the inability to purify the tailings from the middlings; this, together with the bran-dusted flour, making the five barrels.

A three-run mill, with two run on wheat and one on middlings, arranged like Mr. Arndt's mill, mentioned above, will have sufficient bolting capacity by the addition of one more reel for dusting middlings; clothing the reel with No. 12 and the other with No. 13 cloth. And another purifier, run all the middlings into one of the purifiers and finish up the tailings with the other. As the above arrangements are given in cases where the mills are using winter wheat, I will say that for hard spring wheat I would put Nos. 11 X and 12 cloth on the first flour reel and No. 13 cloth on the second, for wheat; for middlings, Nos. 12 and 13, and for dusting I would use No. 13 cloth. Hard spring wheat does not require so much bolting surface as winter wheat, and by drying or heating winter wheat you can get along with less bolting surface than without any such previous preparation of the wheat.

Some hints may be gained from the following account of a seven-run mill in the State of Ohio. The burrs are all four feet in diameter, dressed with two-thirds furrow and one-third face, medium close, old stock, turning at a speed of 140 revolutions per minute. The burrs are driven by gear, with springs on the spindle, and grind about six bushels per hour, four run running on wheat, two on middlings, and one grinding "stub-tail" or "red-dog." The wheat-cleaning machinery is as follows, all having the capacity of fifty bushels per hour: First, a separator; second, a smutter; third, a brush, and lastly, a heater, through which the wheat passes before going to the stone. This

mill is using red winter wheat, taking about five bushels to the barrel, and is making 50 per cent. patent flour. The chop from the wheat stones goes to bolts clothed with six feet of No. 10 XX cloth, and the remainder with No. 12 X, on the first reels, and six feet of No. 13 cloth, eleven feet of No. 14, and three feet of No. 0 cloth on the second reels. Flour is taken from all the four reels, as there are that number of reels in this chest, and the chop is divided equally, the returns being made to the second reels and the middlings going to a half chest of two reels 16 feet long, covered with No. 12 cloth, to be dusted. The bran goes to a bran-duster, and the flour from the bran-duster and the dust from the dusting reels are run together with the "red-dog" flour as a low grade. The middlings, after being dusted, are divided on two small purifiers, the tailings being finished up on a No. 4 machine of the same make, and all go together to the two-run stone for grinding middlings. They then go to another four-reel chest, the two upper reels of which are covered with eight feet of No. 12 X and the balance with No. 13 cloth, and the lower reels covered with sixteen feet of No. 14 and four feet of No. 4 cloth. Flour is taken from all four reels for the patent grade. The returns are made to run to the lower, or second reels; and the tailings from the middlings are run to the half chest of dusting reels. The bolting capacity of this mill is limited, but by their arrangement they are enabled to make two grades of flour. The proportion of the grades is fifty barrels of the first run and five barrels of low grade, which, as mentioned above, is the bran-duster, dusting reel and "red-dog" flour. On the 1st of January, 1877, this flour was selling at the following prices in New York city: Patent, $9.50; first run, $8.50, and low grade, $6.25 per barrel. Calculate the matter for yourself, and see whether you could make money at these figures, the price of wheat being $1.25 per bushel.

A change was made in the cloths of an Indiana mill by taking off eight feet of No. 12 and twelve feet of No. 14 cloth from the first reel, and substituting No. 10 XX all the way through. A No. 15 cloth, used to dust the middlings, was then taken off and put on in its place the Nos. 12 and 14 taken from the first reel: so prejudiced were both the proprietor and miller in favor of fine cloths that they believed it impossible to obtain good results with the cloth substituted, but after running twenty-four hours they acknowledged that their flour had been improved in quality fully twenty-five cents per barrel. Their middlings were much better dusted and could be purified without waste, and, in short, they were more than pleased with the change.

An experienced miller says that "in considering the question of clothing the reel, account must be taken of how much is ground per hour, and whether a purifier be used or not. For instance, if the capacity be six to ten bushels per hour, with no purifier, a 24-foot reel, 36 inches diameter, might be clothed with two feet of No. XX 9, ten feet of No. X 10, eight feet of No. X 10, and the balance, No. 4, for middlings. The slide might be arranged so as to cut of and return within six feet of the head of the reel when necessary. If there is a purifier, and the ground middlings be rebolted on the same reel, the reel may be clothed with twelve feet of No. X 11, eight feet of No. X 12, and the balance, No. 4 cloth, at least one-third of the feed

entering the head being returned ; and if there be not enough capacity, more reels and cloths should be got." The same miller states that if the speed of a reel is increased by say ten revolutions, and the same amount of work required of it, a coarser cloth will be required, because the sliding motion of the material in the reel is, to a certain extent, destroyed, and a revolving motion given instead, which of course decreases the capacity. Now, if the pitch be increased say one-fourth inch to the foot, a coarser cloth will also have to be used, providing the same amount of work is required, because the material acted upon will be carried along with greater velocity.

If possible, each chest should be clothed to suit that run of stone which supplies it.

To Get Out Middlings.—In order to get out middlings, clothe the head of the reel with fine or flour cloth, next coarse cloth, and between the latter and the feed middlings cloth at the tail end, silk coarser than the flour cloth and finer than the second strip. Say thirty inches in a 10-foot bolt, No. 15 at head, then thirty-six inches No. 8 ; thirty-six inches No. 9, then eighteen inches No. 4. The flour from the No. 15 is returned and rebolted. The increasing fineness of middlings cloth raises the grade and makes it uniform—as the coarse particles of grain and pieces of hull cannot pierce the lower end.

A correspondent of the *Millers' Journal* asked how to clothe a 36-inch 20-foot custom reel to bolt the product of one pair of burrs. To this the reply was : " There are so many methods in use, and so many different opinions among millers as to the best, that it is difficult to answer your questions in a manner which will satisfy all. We will say, however, that the practice which has given very good results is to cover your reel with No. 10 cloth. Many millers use four to six feet of No. 9 at the head of the reel, and the balance No. 10 or 11, except ten or twelve inches of coarse cloth, No. 2 or 3, at the tail of the bolt to take out the shorts. This is for custom work. You have quite enough of bolting capacity in the size of the reel you mention for one run of burrs, grinding eight or nine bushels of wheat per hour. Some millers, however, would use a finer cloth than No. 10 or 11—say No. 13 or 14. There is quite a difference, however, in cloths, and even in the same cloths some will become fuzzy, and others remain smooth until worn out. The best motion for a 36-inch reel would be about thirty-two revolutions per minute with half an inch fall to the foot."

Sometimes a mill puts in a run of burrs for merchant work only, for which a small separate bolting chest is desired ; but the power being limited, only a few reels can be used, if possible only two reels, but if necessary to good work, three. The chest is intended to handle the product of two run of burrs, although generally used for but one. The following description of a three-reel chest will be of use to those having need of such a chest as referred to.

" In the three-reel arrangement they are placed one above the other. They are run to separate the fine from the coarse offal, the fine flour coming out last. There is a conveyor under each reel. The cloths become finer in the second, and the third has, generally, No. 12 at head, No. 4 at tail, and the mid-

dlings from this are conveyed to the purifiers. Long reels are of the old school, the tendency on the part of new process millers being to use 16-feet or even shorter reels. A 36-inch reel is too large in diameter, as cloths which

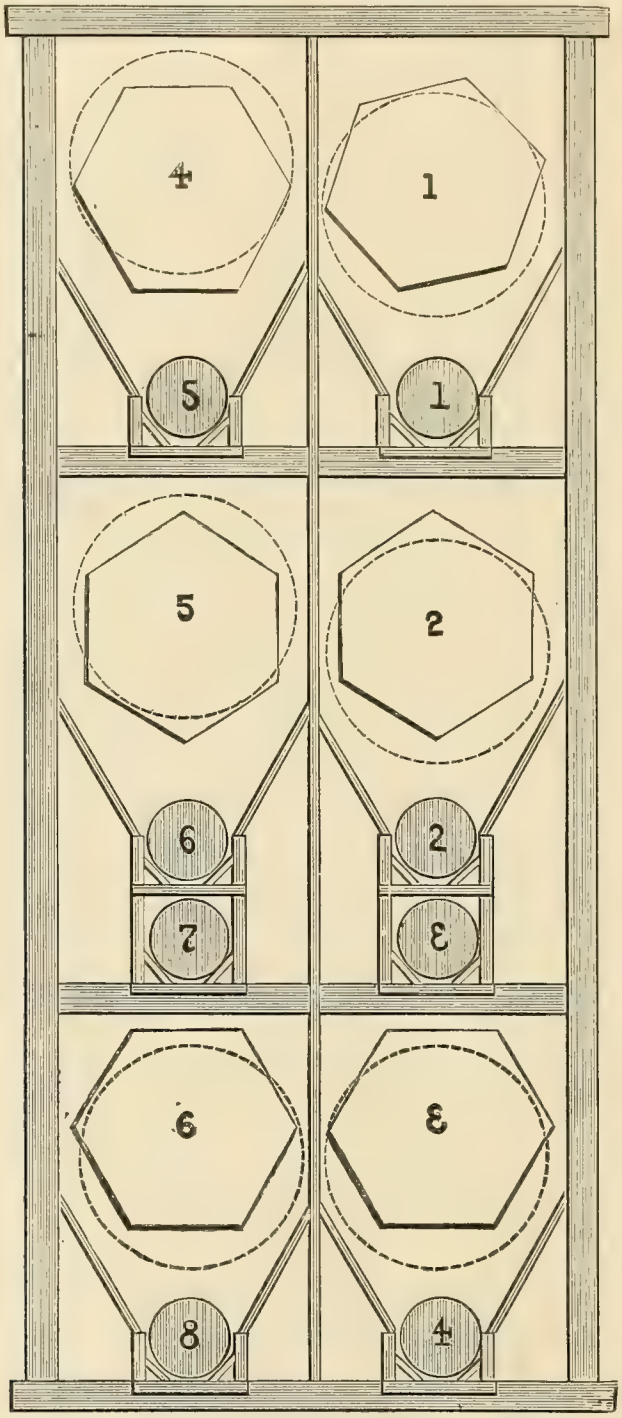


FIG. 303.

are generally 40 inches wide would fit a 30-inch reel much better. Many new process millers use what is known as a scalping reel, in which the bran and middlings are separated from the flour. Then the flour goes to a finer reel,

and so on; but this is rather a complicated system." An arrangement with two bolts, one above the other, to make new process flour is as follows: "The meal, as it comes from the burrs, should pass through the upper reel covered with, say, sixteen feet of No. 10 cloth and four feet of No. 4, as described in answer to No. 1. The flour from this should pass through the second reel, covered with sixteen feet of No. 12 cloth and four feet of No. 3 cloth. At the head of second reel cut-off the first and second grades of flour, and purify and grind the middlings that come from No. 4 cloth on both reels. Then run the ground middlings into the lower reel, after grinding it on a separate stone, or by itself on any stone. This latter plan will be found to give satisfaction, and by that means the upper reel can be used for custom grinding without interfering with the other arrangements."

Clothing for Single Reel.—A single reel, 20 feet long by 32 inches diameter to bolt six to eight bushels per hour, old process, can be clothed with eight feet of No. 9 at the head, then ten feet of No. 10, and two feet of No. 4; speed twenty-eight revolutions per minute.

A reel, 24 feet by 36 inches diameter, with four feet of No. 9 XXX at the head, fourteen feet of No. 10 XXX, three feet of No. 6 and three feet of No. 3 will make good family flour. The pitch may be six to eight inches, and the speed thirty revolutions per minute.

Three Reels.—A new process custom mill of two or three stones may have a bolting chest with three reels. Three are better than two, as giving capacity to thoroughly dust the middlings from the fancy or middlings reel. Grind the wheat with one run if you have only two, or with two if you have three, and the middlings with the balance. Send the chop to the first reel, bolt out the coarse middlings and bran, send the flour to the fancy reel with the flour from the middlings stone, and send the middlings to the purifiers to be purified and sent to the middlings stone. The first reel should be so clothed that it can be used for rye, buckwheat and so on, without using the others.

Six-Reel Chest.—Figure shows the arrangement of a chest of reels for making a straight grade or patent flour. As shown, the height is 17 feet; width, 6 feet 6 inches; capacity, five barrels per hour; length of reels, $13\frac{1}{2}$ feet between bearings; length of bolting surface, 12 feet. About twenty-one and a half pounds of chop per minute enters reel No. 1 at this end of the chest. No. 1 is clothed with Nos. XX10 and X12, one-half of each. The flour is discharged at this end. The return is spouted over No. 2 into conveyor No. 3. What goes over the tail of No. 1 is elevated into No. 4, clothed with middlings cloth, full length, the bran discharging at this end of No. 4. The middlings, being in No. 5, are carried to the back end and discharged into No. 5, clothed with No. X12 one-third of its length, and with No. 14 the rest. That portion of the flour which is clear enough is dropped from the conveyor No. 6 into conveyor No. 7, which carries to this end, and the flour is discharged into the spout with that from conveyor No. 1. The rest of the product of reel No. 5 is dropped into conveyor No. 8, and the middlings from the tail end of No. 5 dropped into reel No. 6, which is clothed with Nos. 14 and 15X. What is dusted from the middlings on reel No. 6 is conveyed to

the back end and discharged into the elevator that carries from No. 1 to reel No. 4. The reground middlings are elevated into reel No. 2, clothed with half chain of No. X 12-14.

Conveyor No. 2 carries to this end and discharges its flour there into the spout with the flour from the conveyors Nos. 1 and 7, or separate as desired. The return from reel No. 2 is dropped from conveyor No. 2 into conveyor No. 3. What goes over the tail of reel No 2 is also dropped into conveyor No. 3, which carries to this end and discharges into reel No. 3, clothed with Nos. 14 and 15. The entire product of reel No. 3 is returned to reel No. 2. After making a straight grade the conveyor may be full the carrying way and one-quarter in the opposite direction, which will mix the flour.

Scalping.—The scalper is to get the high ground meal to the proper consistency, so that it will bolt well in the fine reel. Although most numbers have been tried on the scalper, from No. 000 to No. 9, many prefer No. 7 with a few feet of No. 00 at the tail to take out the coarser middlings from the bran. It has been suggested that the numbers on the scalpers be so arranged that middlings can be graded on it.

Many millers contend that better bolting can be done with all of the bran in the chop, as all of the bolting will be done freer. With hard winter wheat there is very little doubt that the scalper is an advantage.

In the matter of taking out the bran first, it is considered by some to be best to do this if the wheat be the soft winter variety and there be no heater. But where there is a heater, the bran can be taken out to advantage.

Brown says, in the matter of scalping, that it must be done with fine cloths.

For taking out the bran he recommends no coarser than No. 6 cloth, and no finer than No. 9. For scalping the bran from hard winter wheat chop, Brown recommends No. 9 cloth.

Dusting Reel.—The dusting reel for middlings is clothed with No. 12 or finer, and leaves the middlings sharp and distinct. After this comes grading, or it ought to come here, because fine and coarse middlings require different treatment in the purifier. Hard wheat and high grinding require comparatively coarse cloth, and soft grain and low grinding take finer. The dustings from the middlings may be run where they can best be put.

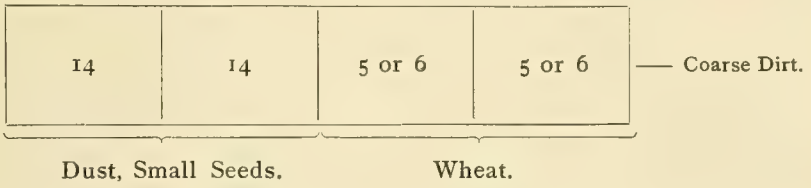
Custom Work.—We have been unable to see why millers will treat farmers, who are consumers, differently from merchants in the matter of product. It seems to us that to make a small mill pay, as much grist work as possible should be got, and the best way to get and keep this kind of trade is to give the farmer good flour. It is the best policy to put in a good custom reel and give the farmer the best grists that you can make. Run only one set of reels with cut-off slides to suit the grinding for one to two 4-foot burrs. Have the best arranged set of burrs possible, with a good long dusting bolt to prepare middlings for the purifier. The money that the custom reel would cost will buy a pony burr for grinding middlings.

"This is not the best way, however, to economize. It would be far better if all of the reels were of the proper length. The dusting reel need not be over sixteen or eighteen feet long, and must be covered with a fine cloth, say

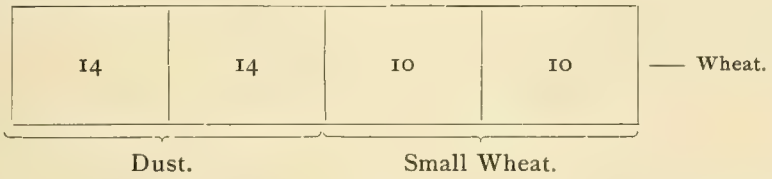
No. 14. The dusting reel should be so arranged that the middlings can pass directly from it to the purifier, where they are graded, and if in a small custom mill, sent to the middlings stone, ground, rebolted, and if for a customer, mixed with the flour from the first reel. This plan will be found to work well in a small custom mill."

Altering Reels.—"To reconstruct an old-fashioned bolting chest, take off all the cloths on the cant-board, move the conveyor from between the two reels directly under one of the reels, and put in enough conveyors to have two for each reel. Place all of the heads one way; run the partition down the middle to the chest, and put in cant-boards for each reel. To get out the bran first, there will have to be a reel with one conveyor put in above the chest. To alter a two-reel chest, it is only necessary to put two conveyors under each reel and pitch both reels one way.

Reels in the Hungarian System.—For taking out impurities, the arrangement shown on page 265 will answer; or it may be somewhat varied, thus:

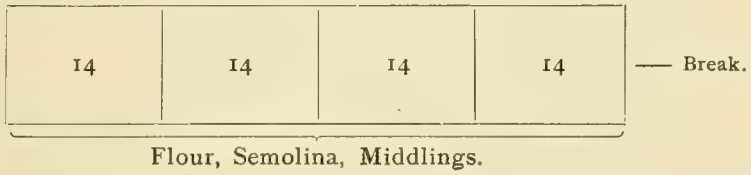


The wheat from this first reel may run to the ending machine, and then to the second reel thus clothed:

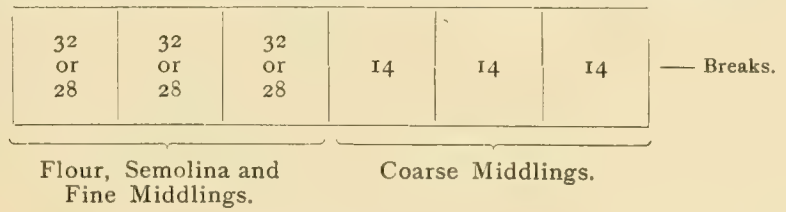


to take out dust and small grains. If the grain is rye, then No. 12 will be substituted for the No. 10 on the last two sheets. The reels under the first break or splitting may be clothed with No. 14.

The first scalping reel proper may be about seven feet long, and thus clothed:

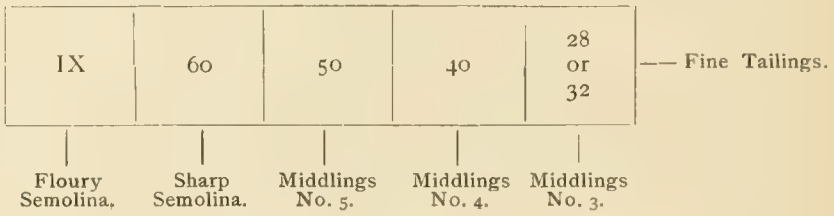


The next scalping reel, 12 feet long, may have the first three sheets of No. 32 for slow-running stones, and No. 28 for quicker running mills.

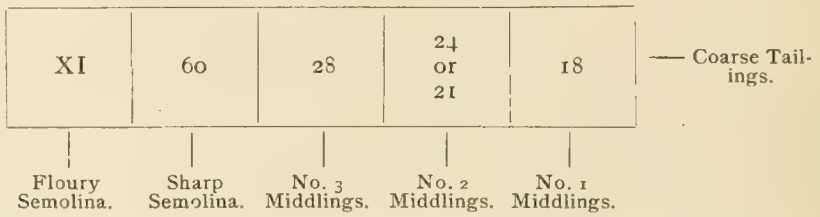


The mixture of flour, semolina and middlings may run to the 12-foot reel, clothed with Nos. XI. and XIII. Or, there would be used by some the Nos. XII., XII., XI., XI., or XII., XI., XI. and X. Opinion seems to incline to placing the coarser numbers first, because their proportion of bran material holds a much larger proportion of flour. Later on, the proportion of bran is in the increase, tending to speck the flour even through finer cloth than at first give a clear product.

In many mills the middlings is taken out by a special semolina reel, through which the mixture of semolina and middlings from the flouring reel is run; thus

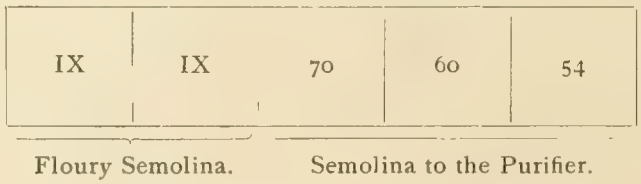


first with No. 9 silk, to let the fine floury semolina through, which latter goes to a dusting reel to free it from flour. The second sheet may be wire No. 60 or silk middlings gauze No. 6, to take out the sharp semolina, the last three sheets being for the middlings Nos. 3, 4 and 5. The coarse middlings reel has upon the first two divisions Nos. XI and 60 to let through any flour, semolina and sharp semolina that might have remained with the coarse middlings. The last three divisions are covered with Nos. 28, 24 and 18, the 24 being replaced by 21 in very rapid grinding. Through this last there passes the middlings Nos. 3, 2 and 1, bound for the middlings purifier, the coarse tailings passing over.



As the middlings prepared for the first purification cannot be naturally freed from flour by the first dusting, the fine middlings—the product of the first purification—must be dusted upon a reel covered with Nos. X, X, 50, 40 and 32; before the third purification there will be the dusting reel covered with Nos. IX, 60, 50, 40 and 32; and for the coarse middlings before both the first purifications there will be a reel covered with Nos. IX, 60, 28, 24 and 18.

The semolina reel and the middlings flour, to free the semolina from light material, will be covered with the following numbers:



Wire-Clothed Reels.—In England circular reels of brass wire cloth are more used than here. They generally have a revolving brush inside, which increases their capacity. Such reels are made in two halves, which can be put together over another reel of brushed, revolving slowly inside. Such a reel is made about six feet long and two in diameter, having arms or semicircles six inches apart around the inside of lengthwise ribs, which keep them in place, leaving the inside free for the cloth and the brushes.

The Centrifugal Machine.—From the *Millers' Journal* we quote the following :

" There are a great many centrifugal machines in use in England, and no mill is considered well equipped without one. The great complaint in a great many cases in numbers of our best mills is, that there is not enough of bolting surface and capacity, and there is a complaint of want of room to put up more bolts in many instances. Bolting chests take up a great deal of room, no doubt, and now that purifiers and scalping reels have become necessary articles, there is more call for space than formerly. It is a very difficult thing to introduce new articles of machinery from abroad, and the centrifugal bolt being a transatlantic machine we are slow to adopt it. The flour is thrown by centrifugal force against the cloth in this machine, and the machine is much shorter than our reel, and travels with a very high velocity. Many machines of this class are only five feet long, two feet wide, and four feet high, and they are said to have a capacity of nearly 600 pounds per hour, and can be made with a much greater capacity if desired. The cloth wears faster than the cloth on the old style of reel ; but then that is compensated by the fact that there is much less of it used on the centrifugal, and its greater capacity is another thing in its favor. Besides this, the action of the centrifugal helps to clean the bran by disintegrating the chop. This is particularly the case when the milling has been done with rolls. It disintegrates the flour in such a way that any of it which might have been flattened by the rolls is completely pulverized, and will not pass out with the bran. Some say that the flour is not quite so clear as that made with the ordinary reel ; but if rebolting is recommended by the reel, why not by the centrifugal machine ? Flour made by the smooth chilled rolls is sometimes sent to the bolt in such large flakes that the service of a détacheur is often necessary to prevent great waste. It is said to act even better than a détacheur when the chop is caked by the rolls, and it is claimed that it is the best device yet discovered for dusting middlings.

" The principle of the construction of the centrifugal machine is somewhat as follows : There is an outer and an inner cylinder. The outer one is covered with silk, and revolves slowly. The inner one revolves rapidly, making between five and six hundred revolutions per minute. This inner cylinder is fitted at its periphery with zinc vanes, which take up the meal and fling it against the silk on the outside cylinder. The vanes are fitted in a spiral direction from one end of the cylinder to the other, and the meal is therefore pushed forward at every revolution parallel to the axis. The meal describes a spiral line, and the middlings pass on and fall out at the end of the cylinder. Funnels and creepers are fitted for the outlets of the different

sorts of meal or flour, so that the meal is spread over the entire surface of the cloth instead of being thrown only on the bottom, as in the reel, and therefore a much smaller bolting surface is required to obtain the same result as the large bolt.

"The separation commences on the first frame of the sieve and every particle comes in contact with it. The meshes of the silk never get clogged on account of the velocity of the inner cylinder and its great centrifugal force, and the meal is separated by the weight of its particles as well as by its size, so that the advantage of this in grading middlings is apparent. There are several varieties of this machine, and one characteristic is that they are all short, not over six feet in length. The material inside of the reel is kept in constant motion and agitation, and all of the particles which may have only become flattened by the rollers are completely broken. The meal is impelled against the silk in a properly constructed machine by successive blows of the beaters, the heavy particles by this means maintaining their velocity and passing more readily through the meshes of the silk than the light, but the constant volley of atoms thrown against the silk and rebounding therefrom, keeping the openings practically clear, render the silk area of greater value than in the regular bolting reel. In order to have the reel do its work properly, the feed must be very regular. There must be no sudden slides of meal, with intervals between them, or the bolting will not be well done. Each revolution must determine the discharge from the reel and dress its own stuff. In order to keep the flour in sufficient contact with the silk, the beaters should revolve at such a distance from it and at such a speed that the flour will be thoroughly cleaned and freed from bran. The angle of the face of the beater should be so arranged that the particles will fly squarely outward to the covering and not at an angle to its surface, because if the particles hit the cloth at any angle the full benefit of the mesh will be lost.

"The beaters should be susceptible to every alteration of their angles, so as to vary the speed of the chop through the machine. An obtuse will pass it quicker than an acute angle. Great care must be exercised that the revolving beaters do not act as a fan, drawing a current of air through the feed, as this renders the machine far less effective. This can be easily understood. When it is considered that a current of air through the silk has only to be strong enough to stop up the meshes, and the more holes or meshes are stopped up in this way the stronger is the current through the remainder and the more firmly are the particles held against the orifices, and besides when a current of air is established it drags the light particles of gray material and bran through the meshes into the flour which otherwise would not have weight of themselves to pass.

"Besides this, the blast is objectionable to the miller whose ideas are perfect cleanliness, and to whom a puffing spout is an abomination.

"Those millers who have made a thorough trial of the centrifugal claim a superiority for it over the reel. The chief points in its favor are that it bolts clearer, occupies a smaller space than the bolting chest, and does considerably more work, besides bolting clearer and agitating the meal better than the bolt. On the other hand, there are many who do not approve of

the centrifugal, on the ground that it is expensive, its construction is difficult, and that it requires too much power to operate it, so that, like every other machine in milling, the centrifugal has its advocates and enemies."

Figure 304 shows a Swiss system of "détacheur," or centrifugal bolts, comprising three reels, of which *a* receives the reduced or flattened middlings and lets the flour and fine middlings pass into reel *b*, which bolts them. The coarse offal and the middlings from the tail of the reel *a* pass into *c*, where they are bolted.

Fig. 305 is an arrangement for low milling. There are three reels; *a* and *a'* receive the chop at the same time, and send the fine middlings into the reel

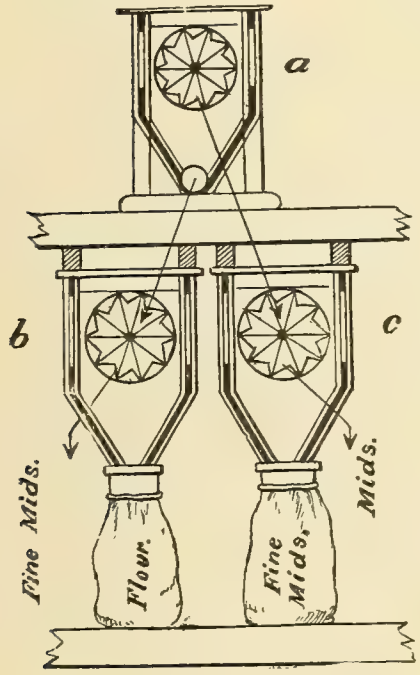


FIG. 304.

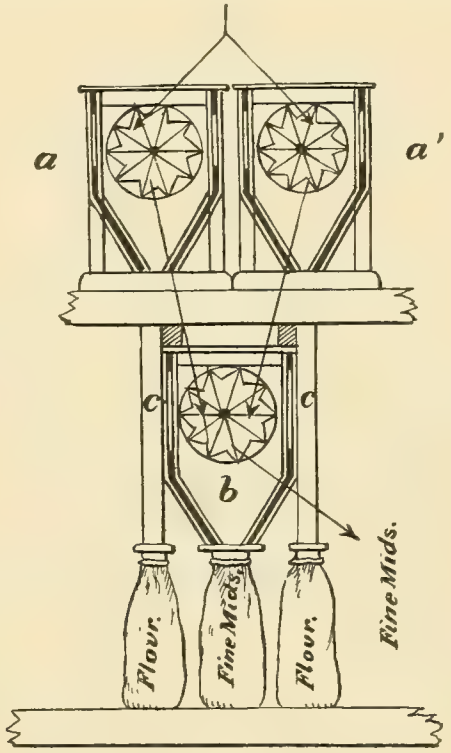


FIG. 305.

b, which separates them; then they are sent to other appropriate sacks. The flour from the reels *a*, *a'*, is taken to the sacks by the spouts *c c*.

Fig. 306 shows the arrangement for high milling. There are four reels, of which *a* lets fall the flour, fine middlings and offal, and sends the coarse middlings to the cylinder *b*; this one lets the flour, fine middlings, etc., through, and the other material tails over to the reel *c*. The flour and the fine middlings are sent to the reel *d*, which separates them and discharges them into proper spouts. The reel *c* sorts the fine middlings, the red stuff, and the bran, which it sends to proper spouts.

Wheat Meal Purification.—The object aimed at by wheat meal purification is to produce a pure granular flour, free from any admixture of the outer coatings or the abraded portions of the berry produced in the act of reducing the wheat to flour. The inventor claims that it being lighter in specific gravity than the pure flour, it readily yields to the influence of as-

cending air currents. He states that in half high milling this material exists in the wheat meal to the extent of 10 to 15 per cent.; he also claims that by removing 5 per cent. of this inferior matter before bolting the chop, the flour first bolted is enhanced in value fifty cents per barrel, and that by removing 10 per cent. of the same, the flour is further influenced one dollar per barrel. He further claims that the material removed by the gentle air currents is not wasted and can be bolted on an ordinary reel, when a fair, salable super flour is secured. If what the millers now using the process have accomplished by it is correctly stated, it certainly seems very absurd for them to send their chop direct from the reducing mechanism to the bolts, without first effecting a purification of it.

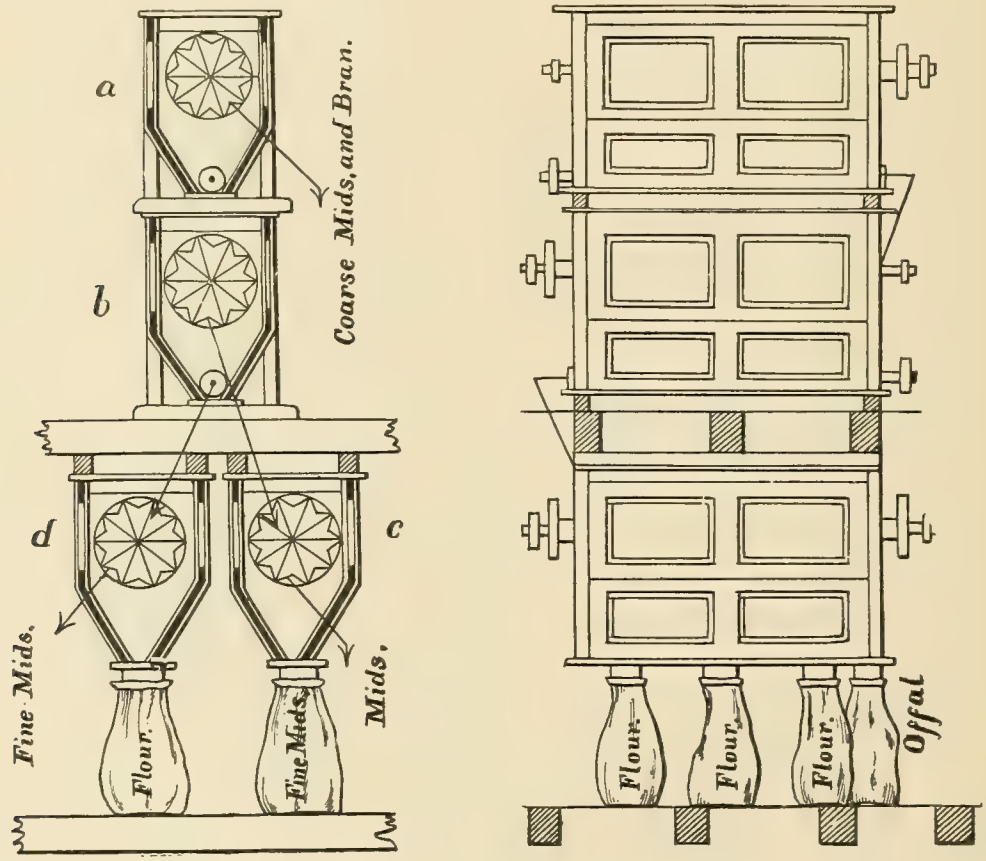


FIG. 306.

Rebolting.—Rebolting gives good results—scalping the bran out first on a wire reel and then putting the flours through two or three reels with one cloth. If ship stuffs are too rich they must be bolted again through a very fine bolt.

Bolting for Custom Mills.—One proposed arrangement of reels for a custom mill plans to have two 30-inch reels, sixteen feet long, making twenty-eight turns. The first reel has ten feet No. 6, four feet No. 4, and two feet No. 0. The tailings go to bran bag. The product of the Nos. 4 and 0 goes to the smooth rolls, where the middlings are sized and the germ flattened. What passes through the No. 6 goes to the second reel, clothed with six feet No. 11 and ten feet No. 13. The clear flour from the

head is sacked; the returns go to the first reel, the tailings to the purifier. Each reel has two conveyors and plenty of cut-offs. In case of damp wheat the finishing reel is thrown out of gear and the flour from the No. 6 cloth sacked. This necessitates that the ground middlings instead of going to the second reel, shall be changed to the chop elevator and run to the first reel. The capacity of such a chest is six to eight bushels per hour.

Another proposed bolting scheme for a custom mill gives two sixteen foot reels, each of two conveyors; the upper conveyor of each reel being the full length of the chest and the lower or return conveyors twelve feet, but projecting one foot beyond the head of the reel. One conveyor under the dusting reel the full length of the chest conveys the dustings to the double elevators. The outside of all the conveyor troughs is flush with the outside of the chest and each reel has strips on three of the ribs to drag the flour round and drop it into the conveyor troughs.

Another arrangement for a custom mill is three feet of No. 10, nine feet of No. 12, and the rest of No. 00 on the chop reel; three feet of No. 11, nine feet of No. 14 and the rest of No. 4 on the middlings reel; six feet of No. 12, the same of No. 14 on the dusting reel.

"Every custom mill should have a separate reel for rye and buckwheat, placed alongside of the wheat bolt, and run from the main shaft by a short shaft for the elevators, and carried to the bolt and conveyor.

"The bearings for the bolts and conveyor should be at least four feet from the head of the chest, and the gear run as near as possible on the inside of the frame. This gives plenty of room to get to the head of the bolt."

A four-run custom mill may be given eight elevators, six starting on the first floor in a line in the centre of the mill. Between the driving belts of the two wheat burrs comes the first elevator for wheat chop, the next elevator is for middlings chop, the third for corn chop, the fourth for clean wheat, the fifth for receiving wheat, and the sixth for receiving corn, buckwheat or rye; the seventh and eighth elevators start on the grinding or second floor, taking the middlings from the bolts to the purifier, and from the purifier to the stock hoppers.

Another recommended bolting plan for a custom mill gives two reels, the upper, clothed with four feet of No. 9, six feet of No. 10, six feet of No. 6, and two feet of No. 0; the second reel has four feet of No. 10, six feet of No. 12, and eight feet of No. 13. The middlings are taken from No. 6; coarse middlings from No. 2, and the bran over the tail; the rest of the product from the first reel going to the second, the middlings will be sent to the wheat meal chop and bolted with this.

A four-reel bolting chest for a four-run custom mill is recommended as having 16-foot reels thirty inches in diameter running twenty-eight, the chop reel not having any return conveyor as the other three reels have, but set down as having room on top for a cooler, the top of which should be on level with top of reel No. 3; the wheat chop passes along the cooler into reel No. 1, clothed with eight feet of No. 12 and eight feet of No. 0. The flour from the No. 12 goes into the fourth or rebolting reel; the product of the No. 0 goes into the second reel, clothed with seven feet of No. 12, four feet

of No. 4, two feet of No. 5 and three feet of No. 0. The third reel, which is above the fourth, is covered with Nos. 14 and 16; what passes through the No. 12 on the second reel goes to No. 4 reel alongside of it, along with the flour from top reel No. 1. The middlings passing through the Nos. 4 and 5 on the second reel go to the purifier, the shorts going through No. 0. The middlings chop reel No. 3 sends flour to meet the first grinding at the head of the fourth reel; the tailings go as feed; all the returns are spouted to the middlings chop elevator to go on to Nos. 14 and 16 cloth on the third reel.

For a one or two run custom mill one miller recommends for the first bolting three reels, one above the other, on the third and fourth floors. The upper reel will be the scalper, and may be clothed with Nos. 6 and 2; the second one may be covered with Nos. 10 and 11. The clear flour from the second reel being run to the flour bin and the rest rebolted on the lower reel, except the returns, which should be sent to the head of the upper chop reel. The lower chop reel should be clothed with Nos. 11 and 12, with a little No. 2 at the tail; the returns from the lower reel go to the head of the upper chop reel. For the middlings there is a three-reel chest, the upper reel being a duster clothed with Nos. 11 and 13 and receiving the product from the No. 2 on the scalper and on the lower chop reel. The flour from the middlings duster goes to the reel below it, the middlings to the purifier. After being floured, this middlings material joins the flour from the dusting reel and enters the first reel under the duster; the clear flour from this middle reel is drawn off, and the balance goes with its returns to the lower reel clothed with Nos. 13 and 14; the tailings from the lower chop reel and from the two middlings reel run to the offal of the purifier. The flours may be run altogether into a straight grade, or the middlings flour may be binned separately as a patent.

A Wisconsin miller in Tennessee recommends for a custom mill two 18-foot reels, the top reel having double conveyors and the lower reel 13-foot conveyors. On the upper reel comes four feet of No. 10, ten feet of No. 11, and four feet of No. 00. On the lower reel there is thirteen and a half feet of No. 12 and the rest of No. 4. The material from the No. 4 is to be sent to the shaker covered with No. 5, which separates the good middlings from the coarse, germy stuff. At the end of the short conveyor the chest should have a partition, and on the reel there should be a circle to keep the dirt specks out of the conveyor. This miller recommends attaching a spout eight inches square to one of the suction fans on the cleaning machine, drawing from the space at the tail of the chest the dust and fluff from the middlings as they fall from the reel into the shaker. The bran is scalped off at the tail of the top reel, the clear flour drawn off and the cut-off rebolted on the lower reel, which gets, also, the chop from the middlings burr.

A custom mill for spring wheat and high grinding may first clean the bran, the chop being sent to a 10-foot scalper, the product of which will go to a second reel, and the bran to the bin. The scalper may be covered half and half, with Nos. 000 and 00. The second reel may have seven feet of No. 9, six feet of No. 10, four feet of No. 11, and three feet of No. 0. The flour will be taken from Nos. 9, 10 and 11, except the returns, which go back to

the head of the same reel; what passes through No. 0 is sent to second purifier, clothed with Nos. 7, 5, 3, 1 and 0; the tailings of the second reel go to an air purifier with the cut-off. The coarse middlings having gone through the purifier and the smooth rolls, go to a small shaker clothed with Nos. 0 and 1, to take off the germ, fuzz, and so on. The product goes back to the head of the second reel, and the tailings to the finished middlings. The meal from the middlings stone goes to a third reel, covered with seven feet of No. 12, six feet of No. 13, four feet of No. 14, and three feet of No. 10. Flour may be drawn from the Nos. 12, 13 and 14, except the cut-off, which goes to the head of the second reel, with the product of the No. 10. The tailings from the third reel and the small shaker are run together for middlings. The tailings of the first reel and of the suction purifier are run together for bran.

A somewhat elaborate bolting plan for a three-run custom mill has eight reels of lengths from six to twenty-three feet. Reel A is a scalper, B a separator, C a rebolter, D and E dusters, F for middlings, G for bran, and H for grading. A is clothed with four feet of No. 1 and two feet of double 00. B has seven feet of No. 9 and ten feet of No. 10. D is clothed with No. 16. E is twelve feet long and is covered with Nos. 16 and 18. F has five feet of No. 13, five of No. 14, and seven of No. 15. G has twelve feet No. 14 and four feet No. 4. H is only six feet long and is clothed with No. 4. The wheat chop from the stone goes into reel A, the bran going from the tail to the bran rolls, and what passes through going into B; the flour from B goes to C, and the middlings to D. The dust from D goes into E, the tail end of E goes to H, and from there to the purifiers. Flour from C goes to the packers as No. 1; the tail end goes to E to be dusted the dust being returned to the middlings chop. The flour from F enters the flour spout leading from C, where it is mixed and carried to the flour chest. The tail end of F goes in with D, being there discharged into middlings grader H. The bran and tailings products after going through the rolls are sent to G; the product of the head of G goes to E, is then returned to the middlings chop, and from there goes to F. The product of the tail of G is dusted on D, sent to H, graded as fine middlings and sent to the purifier.

A three-run custom mill, with one run on wheat, one for middlings, and one on corn, may be arranged to need only five elevators; one to take the chop from the wheat stone, one from the middlings stone, and one from the corn stone to the reel; one which should be used for the smutter, and also, as a storage elevator, and the fifth, to take the wheat from the first separator to the brush.

A plan recommended for an improved grist mill sends the chop from the burr to a 6-foot scalper, covered with No. 0 or 00, according to the wheat. The bran from the scalper goes to the bran rolls; the inside products to a two-reel flour chest—each reel having double conveyors; the first reel has nine feet of No. 12 extra heavy, and the same of No. 13. The second reel, eight feet of No. 14, eight feet of No. 7, and two feet of No. 0.

From the first flour reel there may be drawn for flour, as much as is clear, the rest being sent to the product from the first eight feet of the lower, or separating reel, and these two being sent together as returns to the head of the first reels. As much of the product from the No. 7 cloth as is fit goes

to the purifier, the rest to the smooth rolls with the low middlings, germs and seam impurities. The product from the smooth rolls to a special small bolt, with ten feet No. 13, and two feet No. 00; the bran and ship-stuff may be separated or thrown together as desired. The product from the head of the small bolt, or as much of it as is fit goes to the head of the first bolt, and the rest to feed, or whatever it is fit for; in grist work, it will be fit for feed only.

Still another plan of bolting for custom work, is to send the wheat chop as soon as it leaves the stone to an 8-foot bran scalper, clothed with equal lengths of No. 2 at the head, and No. 1 on the tail. The bran going over the tail goes to the bran cleaner; the meal or chop going through the cloths is sent to a chest having two 18-foot reels, each having double conveyors. The first reel is clothed with six feet of No. 12, six feet of No. 13, three feet of No. 4, and three feet of No. 3, and flour is cut off it to the end of No. 13; what passes through the Nos. 4 and 3 at the tail will be middlings and flour, and will be taken by the lower conveyors with all that you choose to cut off and send to the lower reel. The tailings from the upper reel will go to the ship-stuffs' pile. The lower reel will be covered with eight feet of No. 14 at the head, then six feet of No. 16, two feet of No. 9 and two feet of No. 8. You may cut off finished flour to the end of No. 13; the fine middlings passing through Nos. 9 and 8 at the tail will go to the middlings stone if preferred; the tailings of the second reel will be coarse, sharp middlings, which should go to the purifier. The ground middlings may be bolted on two 16-foot reels, the upper being used as a scalper, and having only No. 10 cloth. The tailings of this reel will be second middlings. The product passing through No. 10 will be taken by the conveyor below to the head of the second middlings reel, covered with equal parts of Nos. 12 and 14; the tailings of this lower reel will be very fine middlings, to be sent directly to the middlings stone. This lower reel may have two conveyors, with slides about half way; from it some finished flour may be cut off, the rest being taken by the lower conveyor to the second reel in the wheat flour chest, clothed with Nos. 14 and 15.

Hints.—Bolting is one of the few operations that had best not be forced; indeed, which must not be forced.

Every mistake or omission made to free the grain reaching the silks must be atoned for in dressing.

Never depend upon the middlings to tell you how the flour is, because they change with the different varieties of wheat.

There should always be a standard flour to work from, and this should be changed every week, so that it will not become bleached.

It is better to have two reels than to have two cloths on one reel.

It is very hard to try to please everybody. There are some people who cannot be pleased, and some who do not deserve to be pleased. It is sad to say, but there are several of this latter class, and several more of the former, among farmers. The custom miller had better stick to a good grade of flour made according to his own experience and judgment, and trust to have it appreciated by all.

Bolts are liable to choke in feeding and must be carefully watched in order that the work may be regular.

CHAPTER XXXV.

ELEVATING, SPOUTING AND CONVEYING.

Elevating—Link-Belt Elevators—Elevator Boot—Elevator Buckets—Air-blast Elevator—Storage Elevators—Hoppers and Sinks—Spouting—Endless-Chain Conveyors—Hollow-Shaft Conveyor—Pitch of Screw Conveyors—Discharge—Flexible Conveyor—Hoisting.

The work of moving masses of material to or from one place in the mill from or to another, within or without, may properly be divided into elevating, spouting and cross-conveying, according to the direction of the material. In the ordinary processes of the mill, elevating comes first, and is followed by spouting and cross-conveying.

Elevating.—In the first case, the material is raised from a lower to a higher level, and this is generally accomplished by an endless traveling belt or chain, traveling upon pulleys with parallel shafts, and having attached to the outer surface equidistant buckets, which pass through the lower "boot," fill with the material to be elevated, and in passing over the upper pulley, being reversed, discharge their load. As ordinarily used, the two folds of the bucket-bearing belt or chain travel in parallel spouts which are slightly inclined.

There are two methods of carrying the buckets: (1) By flat belts, traveling on slightly craning pulleys, of which the upper one receives motion and is hence the driver of the two; and (2) By malleable iron "link-belts," to "chain-belts" running on sprocket wheels, the lower being the driver.

Each of these systems has its advantages and its demerits, according to the surroundings and circumstances.

A very high elevator should be as nearly perpendicular as possible, else the cups will soon wear out. The wheat elevator need not be run as fast as the flour elevator, as the grain, being lighter, discharges quicker.

The great diversity of heights and capacities of elevators render it impracticable for us to give detailed information on the subject, but in making inquiries for specific instructions, the location, height, required capacity, and speed of line-shaft should be given.

Wheat elevators should have revolving spouts, so that in case of storing wheat it can be run to any part of the mill.

If the bolting chests are placed above the grinding floor, the latter set back, the elevator will not come in contact with the hurst, from which it may be separated, as mentioned elsewhere, about four feet, being run upon a short shaft on the second floor, connecting with the main shaft on a movable sleeve beveled gear. The same shaft will answer for driving an elevator for the coarse grain.

The meal elevator should have a valve so that the meal may be run to a shake-sifter or direct to the bag, as desired.

Link-Belt Elevators.—Link-belt elevators, with either single or double strands of chain, as circumstances may require, will, if properly erected and suitable chain and buckets selected, give satisfaction, and too much stress cannot be laid on the importance of starting correctly. We showed in cuts (Figs. 110 and 112, page 217), two styles of elevators; the one having a single strand of chain differs from those now in use, simply in having chain instead of leather or rubber belting to carry the cups. The double strand elevator, however, has new features that will be readily understood and fully appreciated by mill men. The suspended buckets are so hung that the chains support them in a line at or near their centre of gravity,

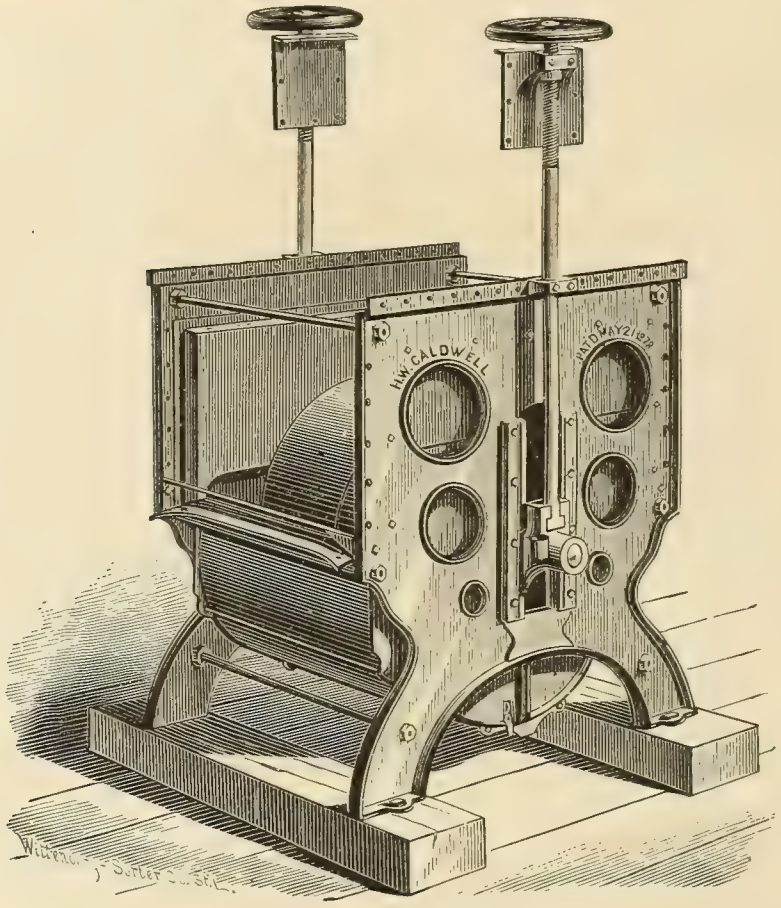


FIG. 307.—ELEVATOR BOOT.

thus relieving the chains of the overhanging strain present in the old forms of elevators. The counter wheels at the head render the discharge much more perfect and independent of any centrifugal action, as the buckets are in turn inverted directly above the shute. This feature gives the elevator a great latitude as to speed, and it will work satisfactorily under all the variations of speed and material that are liable to be met with.

The detachable link-belt and its wheels will fairly wade through grain and elevate, although the boot is filled, and as the supply may safely be kept in excess, the buckets will fill and carry and the elevator work to its full ca-

pacity. One of the most important advantages of the link-belt elevator is that it may be driven from the bottom and with very little tensional strain to keep it at work. The usual type of belt elevator is generally driven from the top, necessitating extra strength in the housing to stand the pull on the belt, and also requiring a main driving belt from the engine clear to the top of the warehouse. Where the link-belt elevator is used and driven from the boot, it is usual to run a line-shaft near the boot and to drive the elevator with a smaller chain than the one which carries the buckets, so that in case an obstruction occurs in the elevator, the light driving chain will break and the elevator buckets and chain saved from damage, just as the chain serves as a safety point in harvesting machines.

Elevator Boot.—The Caldwell Patent Elevator Boot,* Figure 307, is adjustable, because the bottom and sides to the boot proper are fastened to

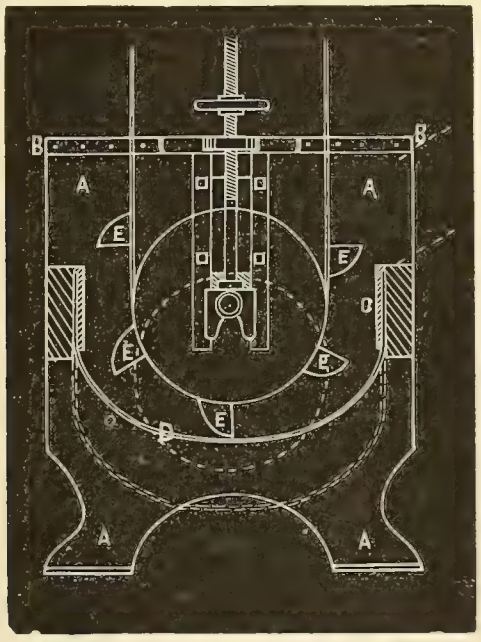


FIG. 308.—ELEVATOR BOOT—SECTION.

the shaft on which the pulley goes, so that when the pulley is raised or lowered to tighten or loosen the belt, this bottom boot or receptacle goes up and down with the pulley independent of the outside ends, and the bottom of the boot remains the same distance from the bottom of the pulley under all circumstances; outside of this inner receptacle are the heavy cast-iron sides that support the leg or trunk, which is made of wood in the ordinary manner. The shaft works up and down in these sides on gibbed guides governed by rods on each fastened to the journal-box, as shown in Fig. 307, and these rods are provided with suitable hand-wheels, situated at the most convenient point for handling, and work on the proper thread. The pulley is raised or lowered by turning the hand-wheels. This inner cradle or basket-shaped

* H. W. Caldwell, Chicago, Ill.

boot has its edges pass up under cast-iron aprons which are securely fastened to the outer part or sides of boot, so that the play up and down is well provided for and leakage is prevented. There is also side play allowed, so that the pulley in the boot can be run off a level, as is often required from some settling of building or stretching of belt, over which there would otherwise be no control. The buckets scrape close to the bottom and take up all the material, leaving the boot clean. This is of great importance in running one class of material after another, or different grades or kinds of grain. There is no mixing of grades in this boot unless two kinds are run in it at once. There is a slide in the bottom easily opened or closed. It cannot easily be choked, because the buckets occupying their proper distance apart on the belt, and fitting close to the bottom, will let in material only in such quantity as the bucket has capacity to take, and any surplus will back up in the feed spout ; so you can start or stop when the feed is on without closing the feed gate.

There are two styles of this boot made, one called "low feed," adapted for large elevators, and where it becomes necessary to have the feed at a low point on the pulley ; the other, or "high feed," is used when the height of

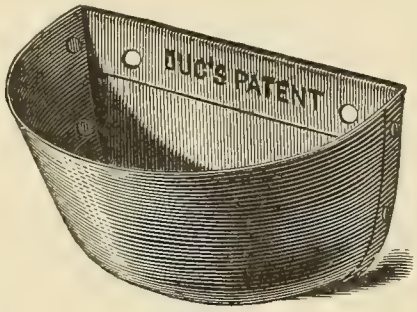


FIG. 309.

feed makes no difference. The parts or sections forming the boot are easily removed in case of accident, and are numbered so that duplicates can be readily obtained if desired. The point of feed is stationary in both patterns ; the rise and fall of the pulley is independent of the feed.

Elevator Buckets.—It is astonishing how, in the great Hungarian mills, they can make a profit when there is so much money wasted in laborers' wages in carrying material from floor to floor and from place to place. The elevator in its present form, invented by Oliver Evans, and introduced by him, in 1783, together with the conveyor, into his brother's mill, is unknown in many European mills.

It is estimated that the elevator, with its twin invention, the conveyor, has effected a saving of 50 per cent. of labor in the mill.

The buckets attached to the endless belt have been made of wood, leather, paper, pig skin, "tin" and iron. "Tin" and iron are most generally employed in this country ; the general shape being the frustrum of an oblique pyramid, the mouth being oblong and the front tapering back. Such shaped buckets have the disadvantage of being liable to accidents from catching in the elevator leg if the belt twists, and in many cases the wrench-

ing they undergo in passing through the material in the boot opens their seams and tears their lips, besides wrenching them from the belt.

The most approved bucket of which we have any knowledge is the "Duc,"* which seems to obviate both of the difficulties we have named. Its mouth is spherical, and the whole outline is devoid of any seams or corners, except where the curved front is joined to the straight back which lies against the belt. In consequence, the passage of such a bucket through the material in the boot is much easier than if it had square corners and entered the material suddenly. It fills more readily and is more apt to take a full load than the oblong bucket, and there being no interior corners to clog, it is more likely to deliver all that it carries up. It is shown in the illustration, Fig. 309. This bucket is struck out by a die from cold-rolled char coal stamping iron, and is manufactured in two weights, viz., light and heavy. The buckets from the light material (No. 24 iron) are intended for use in flour and drug mills, and in any kind of light material.

Of the light weights there are ten sizes made, ranging from $3\frac{1}{2}$ to 10 inches on the belt.

The 12 to 20 inch buckets are made with partial straight fronts. The following table gives sizes, weights and carrying capacities of the Duc bucket:

TABLE OF DIMENSIONS AND CAPACITIES.

On Belt (width).	Projection (broad).	Deep.	Capacity in Cubic Inches.
THE "LIGHT" BUCKET.			
$3\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{3}{4}$	$10\frac{1}{2}$
4	$2\frac{5}{8}$	$2\frac{3}{4}$	$11\frac{3}{4}$
$4\frac{1}{2}$	$2\frac{3}{4}$	$2\frac{3}{4}$	$17\frac{1}{2}$
5	$3\frac{1}{4}$	$3\frac{1}{8}$	$24\frac{1}{2}$
$5\frac{1}{2}$	$3\frac{5}{8}$	$3\frac{1}{8}$	28
6	$4\frac{1}{8}$	$3\frac{5}{8}$	46
7	$4\frac{5}{8}$	$4\frac{1}{8}$	65
8	$5\frac{3}{8}$	$4\frac{3}{4}$	104
9	$5\frac{3}{4}$	$4\frac{7}{8}$	131
THE "HEAVY" BUCKET.			
$4\frac{1}{2}$	$2\frac{3}{4}$	$2\frac{3}{4}$	$17\frac{1}{2}$
5	$3\frac{1}{4}$	$3\frac{1}{8}$	$24\frac{1}{2}$
$5\frac{1}{2}$	$3\frac{5}{8}$	$3\frac{1}{8}$	28
6	$4\frac{1}{8}$	$3\frac{5}{8}$	46
7	$4\frac{5}{8}$	$4\frac{1}{8}$	65
8	$5\frac{3}{8}$	$4\frac{3}{4}$	104
9	$5\frac{3}{4}$	$4\frac{7}{8}$	131
10	$6\frac{1}{8}$	$5\frac{1}{8}$	158
12	$6\frac{1}{8}$	$5\frac{1}{8}$	216
14	$6\frac{1}{8}$	$6\frac{1}{2}$	282
16	$6\frac{3}{4}$	$6\frac{1}{2}$	395
17	7	$6\frac{3}{4}$	436

*T. F. Rowland, manufacturer, Brooklyn, N. Y.

TABLE SHOWING CARRYING CAPACITY OF ELEVATOR BUCKETS.

Size.	Speed 200 feet per minute. No. Bushels per hour.	Speed 300 feet per minute. No. Bushels per hour.	Speed 500 feet per minute. No. Bushels per hour.
5 × 4	250	371	625
6 × 4	275	412	687
7 × 4½	500	637	1,062
8 × 5	600	900	1.500
9 × 5	650	1,012	1,687
10 × 5½	850	1,275	2,125
11 × 6	1,105	1,725	2.875
12 × 6	1,300	1,950	3,250
14 × 6	1,600	2,400	4,000
20 × 6	2,275	3,412	5,687

Air-Blast Elevator.—So far, the air-blast system is very little used, and awaits development. In it we include fan-blast, fan-suction devices, and also the jet or injection principle. For elevating flour the fan-blast

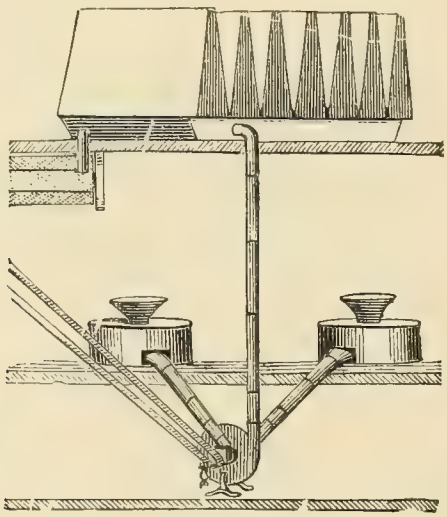


Fig. 310.

elevator has the advantage of cooling the flour. Fig. 310 shows such an arrangement.

Fig. 311 shows a proposed air conveyor arranged near a floating grain elevator in working position between a barge and a vessel; the grain is drawn from the barge through the tube by suction until it reaches and mingles with the compressed air-jet within the contracted section of the elevator tube, being then forced up into a receiver in the upper part of the central vessel through which the grain falls in the usual manner, being again elevated into a tube leading to and terminating in the hold of the vessel. The shifting apparatus then forces the grain into and fills up all spaces between decks. There is an air compressor or blowing engine, B, with suitable air receiver, C C, in which the air should be kept at about 40 pounds per square inch.

Grain Elevators.—Figs. 312 and 313 show sectional end and side views of a large grain elevator. The ground dimensions of the building are 330 feet by 86 feet, and the height is 136 feet. The building contains 264 compartments, of which 260 are bins for storing grain, and the other 4 afford passage for the stairways, belts, etc.

The inside dimensions of each bin are 9 feet by 9 feet square and 56 feet high, including hopper. Below the bin hoppers is a story 16 feet high and extending over the whole ground floor of building. Through one side of this and about four feet below the floor is the railroad track, the cars coming in at one end of the building and going out on the other. The cars are unloaded by means of steam shovels, driven by shaft *b*, by which the grain is scraped out of the cars and dropped into the sinks *c*. There are eleven sinks and as many cars can be unloaded at once. In the bottom of

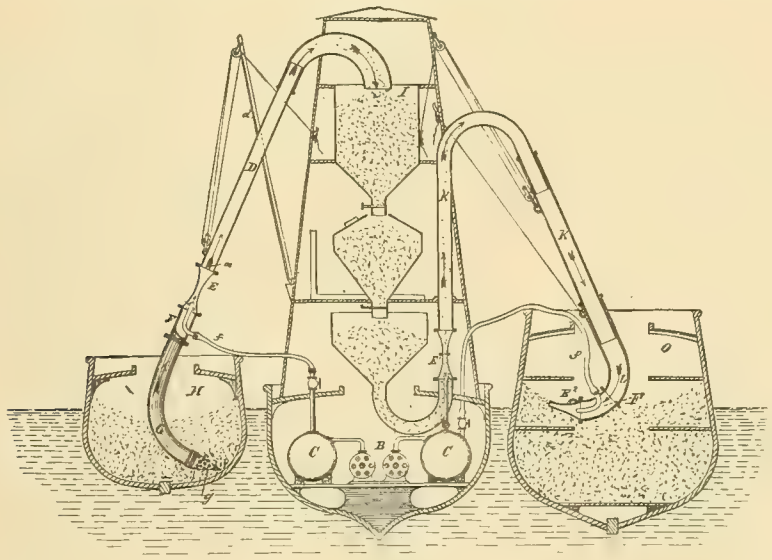


FIG. 311.

each sink are iron elevator boots in tanks of wrought iron calked so as to be water-tight. The elevator boots are provided with slides to regulate the feed, which can be operated from the floor above.

The eleven elevators are marked *e*. The elevator head pulleys are 72 inches diameter and 21 inches face, and the boot pulleys 24 inches diameter and 21 face. These boot pulleys are hung in universal bearings, which may be lowered at pleasure in order to tighten the belts.

The elevator belts are 4-ply rubber, 20 inches wide, having on them 18-inch elevator buckets, very strong, and placed twelve inches apart.

The line-shaft, *e*, in the attic rests in heavy universal boxes, and is provided with expansion couplings. There are eleven sleeves on this shaft, with babbitt bearings and spiral coupling jaws at one end. These sleeves are fastened in no way to the shaft, but have an elevator head-pulley keyed to each one. Fastened on the shaft with feathers are eleven coupling heads with spiral jaws which match those on the sleeves. These heads are thrown in and out of gear with the sleeves by means of forked levers and rings.

When out of gear the sleeve with the pulley stands still and permits the shaft to revolve inside of it. By this means one or more of the eleven elevators can be run or stopped at pleasure without stopping the engine or line-shaft.

The line-shaft, *e*, in the attic is driven by a 42-inch rubber 5-ply belt.

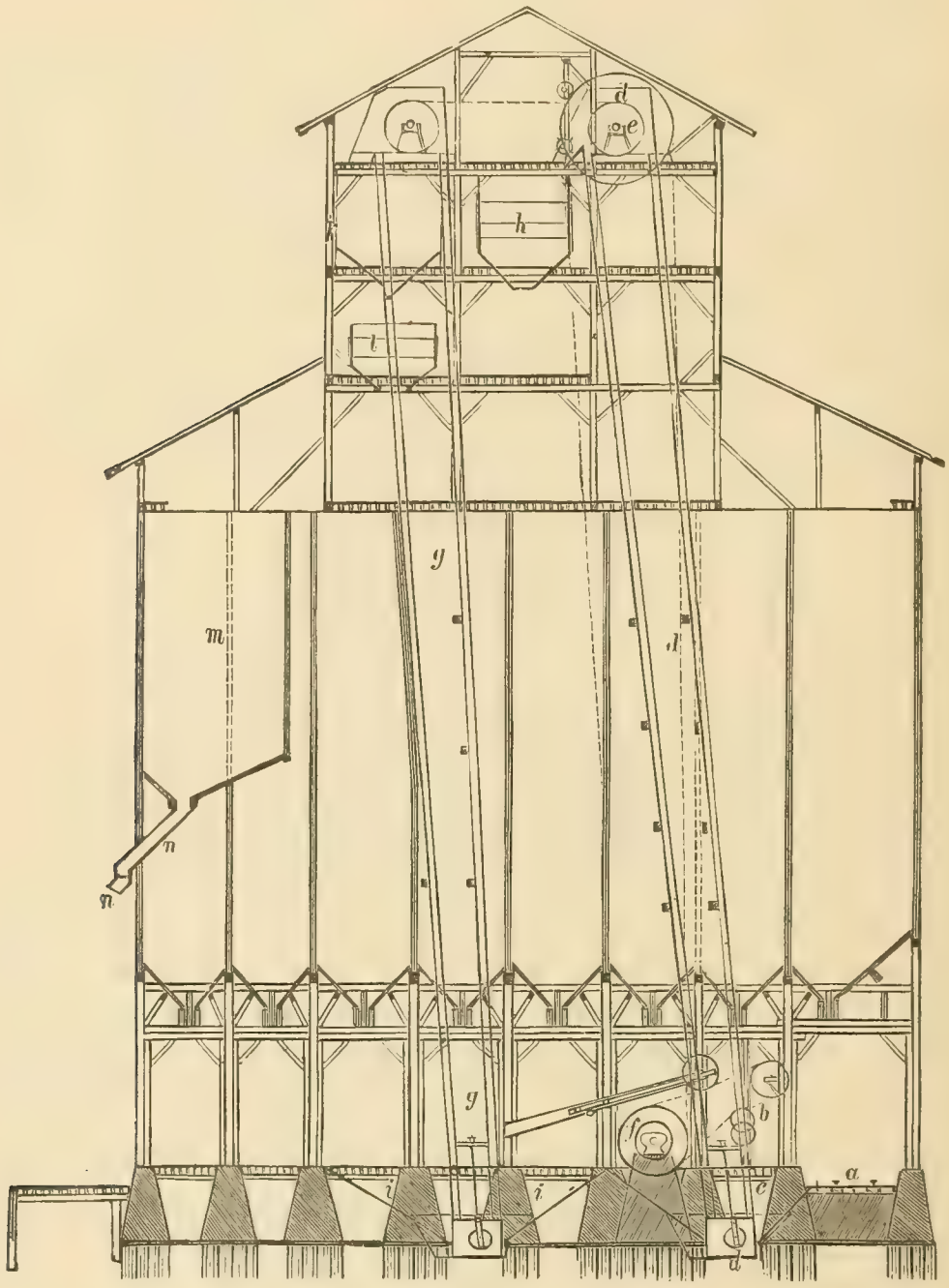


FIG. 312. GRAIN ELEVATOR—END VIEW.

The belt is hung on a pulley 13½ feet diameter and 48-inch face, and is set in motion by a pulley 8 feet diameter by 48-inch face on the engine shaft, *f*, below, and is tightened by a 48-inch tightener.

These eleven receiving elevators, *d*, discharge in the attic into eleven scale hoppers, *h*, where the grain can be weighed and then spouted into

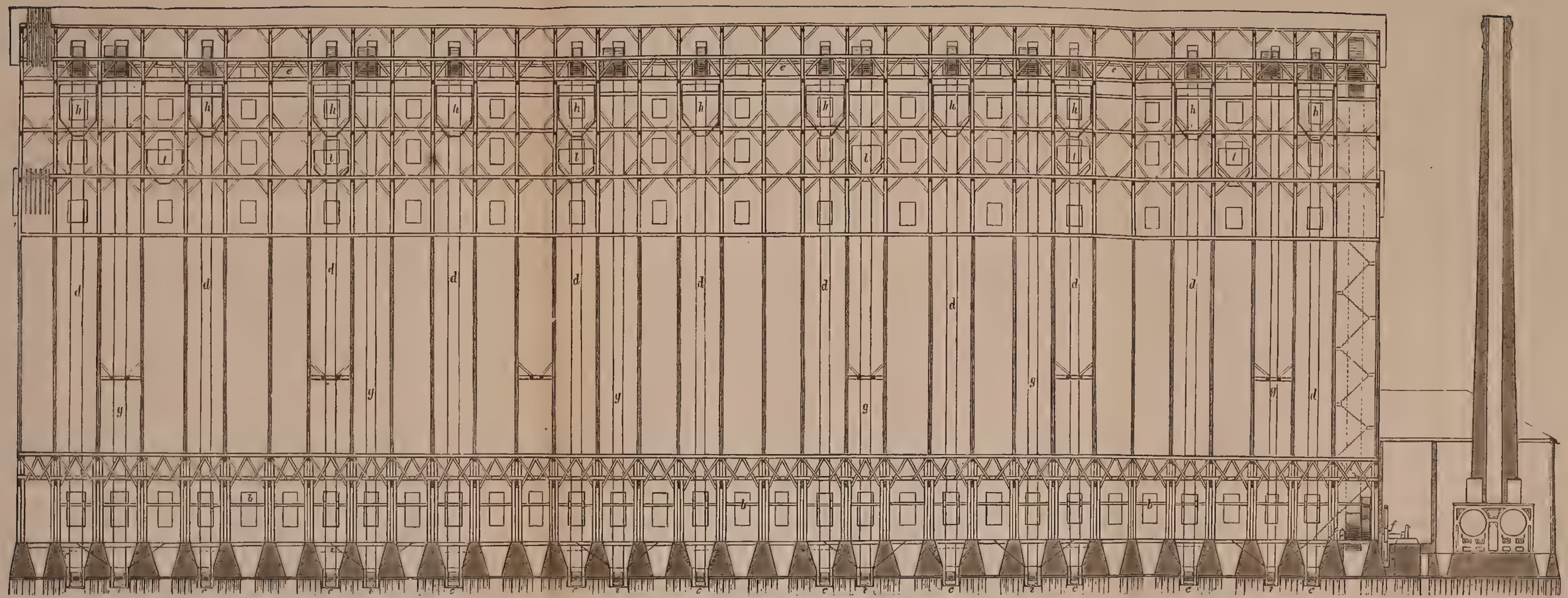


Fig. 313.—GRAIN ELEVATOR.

the various bins below. If it is desired to work the grain over or ship it either by boat, car or wagon, it is spouted into the six sinks *i*, in which stand the iron boots of six elevators *g*, by which the grain is again elevated to the attic and thrown into the hoppers, *k*, from which it is dropped into the six scale hoppers, *l*, where it is weighed and thence spouted out into the shipping bins "*m*," which are only twenty-seven feet high, and thence, by the shipping spouts *n*, put outside of the building, either into boats, cars or wagons; or if it is only being aired, it is spouted from these bins back into the receiving elevators and again taken to the storage bins. The motion to all this machinery is imparted by an automatic cut-off condensing engine of 250 horse-power. The construction of the bins is very simple, they being built up of two-inch plank, ten inches wide at the bottom and reducing in width as they go up to eight inches, then six inches, and finally four wide at the top.

Sinks.—In a custom mill the sinks or receiving hoppers may be placed over the separator, running up even with the grinding floor. There should be a stop slide so that the grain may be elevated for storage, without going through the separator.

When the wheat is received it should be weighed; this may be done by a scale hopper on a truck. After weighing it may be run into the sink.

Wheat may be taken into a receiving sink, a few feet from that end of the reel at which grain is received. This sink is suspended from the second floor and reaches nearly down to the lower floor; the wheat is taken by the elevators to the highest point desired, and carried across by a conveyor.

There should be a coarse screen placed over the corn and feed sink, about twelve inches from the top, to catch any large material which cannot be elevated.

The stock hopper which will be placed over the chopping stones in a burr mill should have two slides, so that the grain may be changed, or run to another burr.

The slides of stock hoppers should be so arranged as to be operated by the miller from the grinding floor.

Spouting.—The grain or other material having been elevated by the endless belt and bucket system, may readily be sent where desired to points on lower levels, but not very far distant horizontally, by simple gravity, being directed by suitable spouting, generally air-tight, and preferably of large section, and having as steep pitch, as few angles, and as smooth interior surface as possible, to obviate clogging or pasting up. For operating, the usual form is rectangular, and the material employed is wood. Of necessity such spouts have waste spaces in their angles; even the constant friction of use will not give them as smooth a surface as though metal were employed, and their putting up or alteration is an expensive task, demanding much time and skill. Such spouts are now being superseded by black sheet iron or tinned sheet iron spouting, which can be bought in sections of convenient length and diameter, and quickly put together. Round metal spouting possesses the advantages of cheapness, smoothness of interior surface, and lack of angles to clog or paste up. Of course, it permits of less steep pitches being used, hence, allows more liberty to the millwright, as to the disposition of the

various machines and hoppers, than wooden spouts do. The slides for inspection are simple curved plates working in slides. As far as possible the

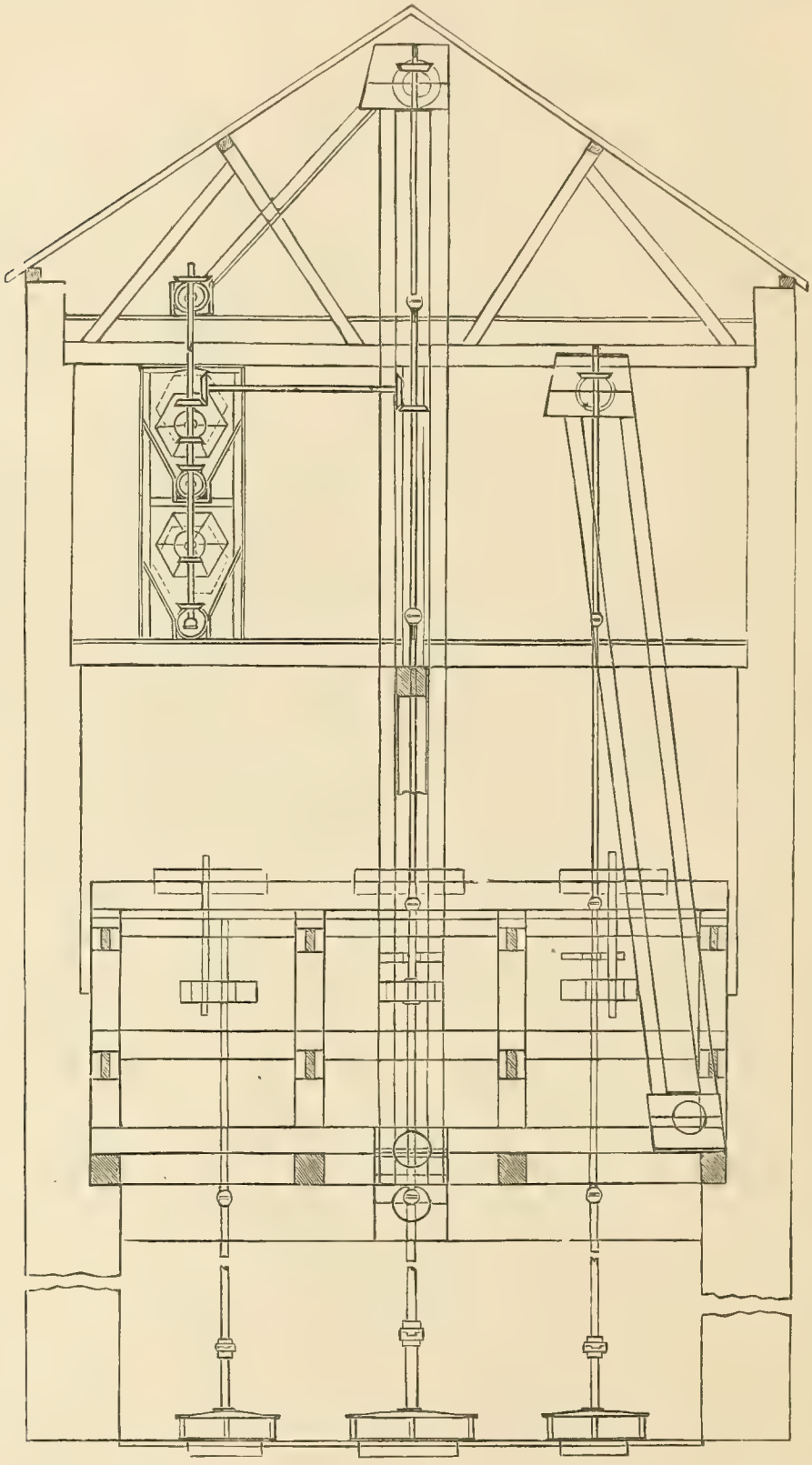


FIG. 314.

mill should be arranged so that there shall be a minimum amount of cross conveying and re-elevating, and a good system of spouting enables the ma-

terial to be put where wanted, with a maximum expense for outlay and power.

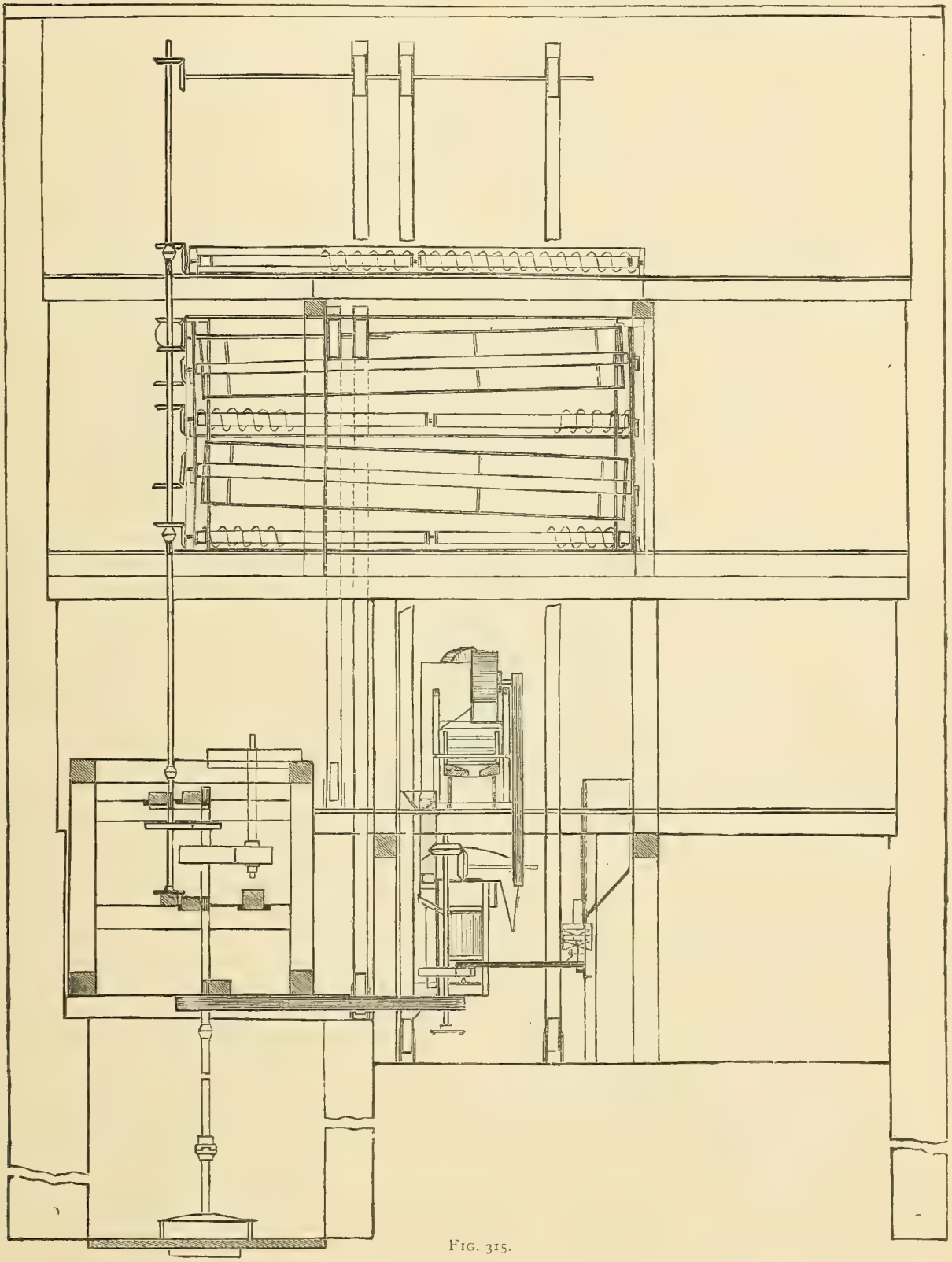


FIG. 315.

The trough of the conveyor at the top of the mill may have short spouts, at intervals of four feet, which will take the wheat from the conveyors to the

bins. Each bin should have at its bottom short spouts to which may be attached an extension spout, to take the wheat to an intermediate hopper to the floor below.

Endless-Chain Conveyors.—One method of cross-conveying is by means of traveling endless chains bearing slats which sweep along the material. Conveyors employing Ewart chain are constructed on two general plans; one in which the slats are bolted on one side of the attachment links and chain either run in a recess in the centre of the trough if the upper run of chain is used, or ride on the top of the slats if the lower run is used. This form is adapted to use in places where the perfect cleaning of the trough is not required. In case the conveyor is to be used in conveying various kinds

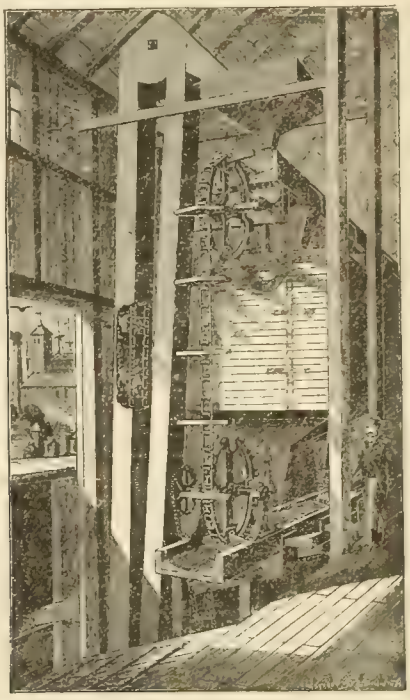


FIG. 316.—DOUBLE FLIGHT CONVEYOR.

of grain successively, the absolute cleaning of the trough is a necessity, and the slat and chain attachments are so made that the chain runs through the centre of the slat, which is lozenge-shaped, the longer diameter being at right angles to the chain and in the same plane as the chain. With this style of conveyor both the upper and the lower runs of the chain can be used at the same time, the upper run filling a bin and the lower emptying one. The shape of the slat is such that it will continue to fit the trough until worn out, and consequently no grain can lodge in the trough, but all is swept out. The wheels employed in this form are made with gaps, at proper intervals, so as to permit the projecting part of the slat to pass the wheel without interfering with the running of the chain.

The Ewart Manufacturing Company, 253 South Canal street, Chicago, makes several sizes of chain especially for conveyors, and can supply the outfits for mills, etc.

Hollow Shaft Conveyor.—The Caldwell patent hollow shaft conveyor* (Fig. 317), is a lap-welded pipe, made expressly for conveying purposes; round, smooth, strong, and in equal lengths, for all standard sizes. The shaft is very small, whereby the material to be moved is brought so near the centre that the leverage and friction on the shaft are greatly diminished. A very small diameter conveyor is capable of doing a great amount of work, as the material is conveyed by the "flight" and not by the shaft. The larger the shaft, the greater the amount of frictional surface; the more power it takes, and the less material it moves. This conveyor is well constructed and eco-

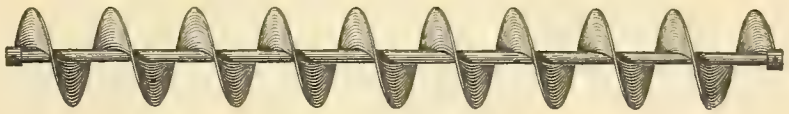


FIG. 317.

nomical in its working. Its construction is on mathematical principles, giving good results with little space and power. It has no frictional or rough points to come in contact with the material, is smooth like an auger, can be run at a very high rate of speed, and will carry grain any distance required. It is made of wrought iron or of steel, galvanized iron or copper. Among its valuable features for bolting purposes are that bugs will not stay about it, nor will they deposit their eggs on it, and it does not carry the material up on the side of the box, but moves it along bodily. The hollow shaft conveyor is made right or left hand.

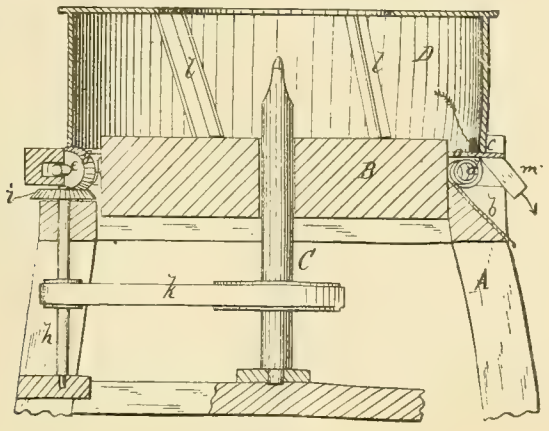


FIG. 318.

Pitch of Screw Conveyors.—On a right-hand conveyor the pitch of the flight gains to the right, on the left-hand conveyor the pitch gains to the left. A right-hand conveyor turning to the right, facing the driven end, carries or pulls toward the driven end; a right-hand conveyor turning to the left, facing the driven end, carries or pushes away from the driven end. A left-hand conveyor turning to the right, facing the driven end, carries or pushes away from the driven end; a left-hand conveyor turning to the left, facing the driven end, carries or pulls toward the driven end. Con-

* Manufactured by H. W. Caldwell, Chicago, Ill.

veyor boxes, with patent cleaning attachments and patent delivery gates, are made for use with these conveyors. The "flights" consist of a continuous

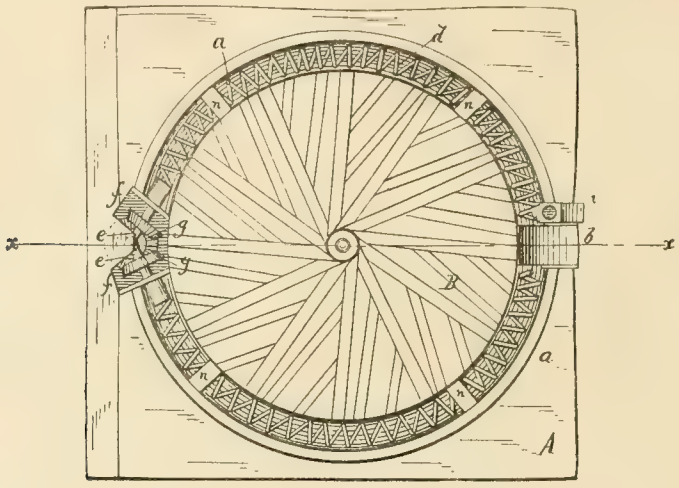


FIG. 319.—FLEXIBLE SPIRAL CONVEYOR.

spiral of sheet iron constructed of flat rings, with their inner and outer circumferences so calculated with reference to the diameter of the shaft and the conveyor that when opened out they make sections having a perfect

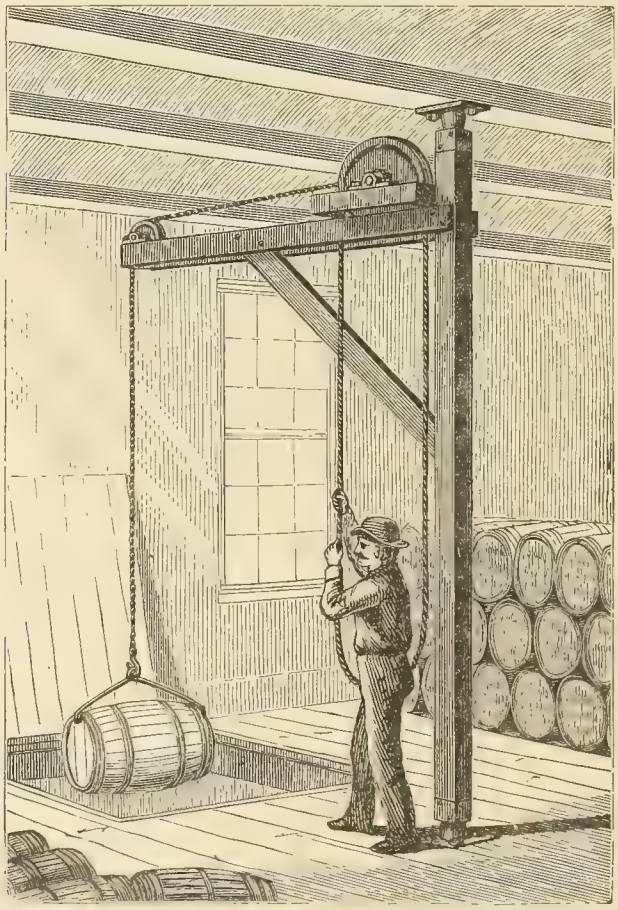


FIG. 320.—WESTON DIFFERENTIAL BLOCK.

screw pitch. Such a conveyor is light, and has great carrying capacity without clogging or springing the shaft by its weight.

Discharge.—Discharge openings should be arranged so as to perfectly free the trough. The openings in the bottom of the conveyor boxes should be on the carrying side of the boxes. Cut the bottom out including the corner piece, commencing at the lower edge of the opposite corner piece, and running it through to the side of the boxes.

Flexible Conveyor.—Figs. 318 and 319 show a proposed chop conveyor, in which there is a continuous channel or passage below the upper surface of the stone and containing a flexible spiral conveyor, driven by bevel gears. It is introduced here as hinting at possibilities in conveying

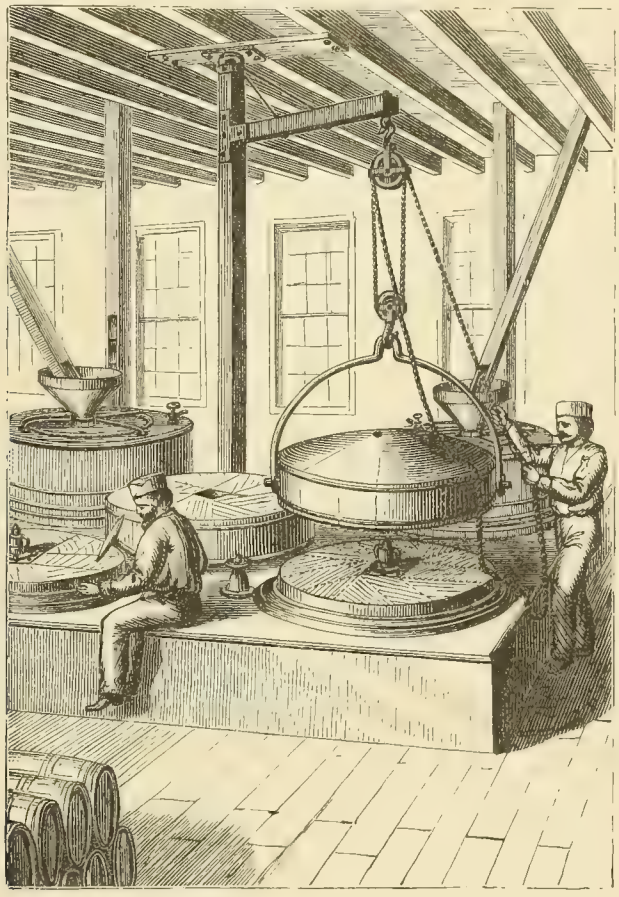


FIG. 321.

material "up hill and around corners," by flexible conveyors in tin spouts of round section.

Hoisting.—For hoisting apparatus for the purpose of elevating machinery or barrels of flour, it is desirable that there should be used some device that will give great power with great safety to the men operating it. In the Weston differential block the load is always suspended and can never run down. Hoisting is effected by pulling one side away and lowering by pulling the other. With the direct block one man can lift 1,000 pounds; with geared blocks, 2,000 to 4,000 pounds, thus saving time and labor, with the greatest safety. They are compact, portable and applicable to many purposes. In Fig. 320 the hoist is shown in use for raising or lowering flour barrels in connection with a swinging crane, and in Fig. 321, raising heavy burrs.

CHAPTER XXXVI.

WEIGHING, TESTING, PACKING, BRANDING AND STORING.

Scales—Grain Meter—Inspection of Flour and Meal—Packing—Economic Flour Packer—Tallies—Adjustable Tally—Electric Tally—Brands, &c.—Storage.

As the preliminary operation of milling comes the weighing or measurement of grain. Deliveries from farmers' hands at elevators or nearest shipping points, and exchanges from storage warehouses to railway cars or other vehicles of transportation and of transfer to the miller require the determination of quantities. Furthermore, after the grain has reached the mill there is still a system of balances to be carried out in order to maintain the proportions necessary for the admixture of grain and its conversion into flour.

FIG. 322.—DORMANT FLOUR-PACKING SCALE, WITH DROP LEVER, FOR MILLERS.

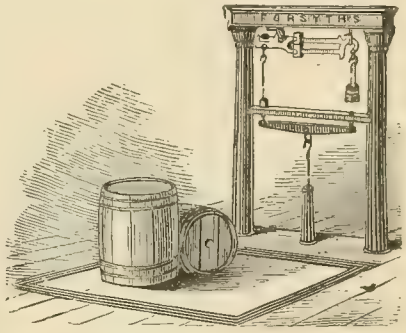


FIG. 323.—DORMANT SCALE, IRON COLUMN AND SLIDING POISE.

Following upon this conversion, another system of checks and tests becomes necessary, until at length the consumer who munches his loaf makes the final determination of every question as to weight or quality.

Starting, then, from the beginning, the accepted standards of weight in pounds per bushel for the different cereals are as follows : Wheat, 60 ; corn, 56 ; rye, 56 ; oats, 32; barley, 48 ; buckwheat, 60.

We are thus brought at once to confront a method of weighing which can only be carried out by the use of scales.

Scales.—Like other machinery, scales have been greatly improved in the last twenty years, and perfect as they now seem to be, improvements are constantly being made by enterprising manufacturers as practical use suggests. The old even-balance beam, with hopper on one end of the beam and standard 60s on the other end, has been supplanted by the more convenient compound hopper beams, using small weights in place of the cumbersome 60s, or platform scales with hopper on the platform, or the still more convenient wagon scales. The arrangement of the levers in the Forsyth

scales* (Figs. 322 to 326), is such that the action of the weights placed upon them is direct, and the motion of the levers in weighing is downward, the same as if hung upon a steelyard beam. The pivots have steel bearing edges, and these rest upon flat steel plates. The levers are suspended to the frame-work of the scales in steel-faced loops, which have steel

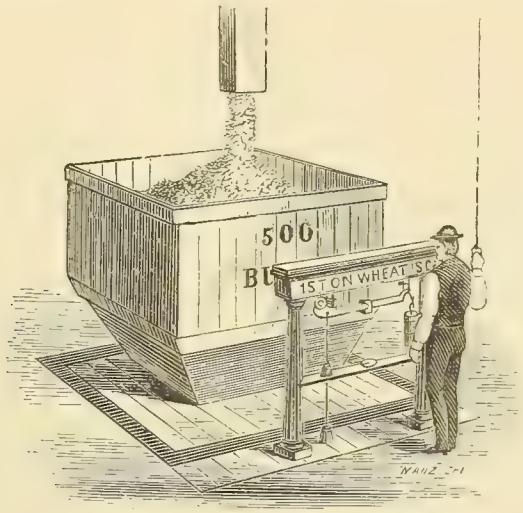


FIG. 324.—HOPPER AND ELEVATOR SCALE, WITH IRON COLUMN AND SLIDING POISE.

guards at the sides to prevent friction against the sides of the levers. The platforms of the scales are held in position by check-rods, which prevent them from moving out of place, without interfering with the downward motion necessary in weighing. By these means the least amount of friction is caused, there being no lateral or twisting motion of the weighing ma-

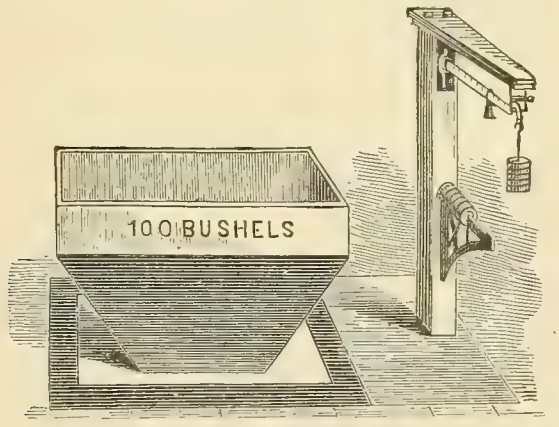


FIG. 325.—HOPPER SCALE FOR GRAIN, WITH WOODEN PILLAR

chinery. The use of wagon scales for receiving scales at mills is more common than formerly, owing to the greater facility and rapidity in handling grain, as well as the less amount of labor required. These scales are made of different sizes, but with long platform scales (8×22 feet platform) the team is weighed with the load, and no variation from correct weight can be

* Manufactured by Forsyth Scale Co., Chicago.

made by the pulling or backing of the team, while the load is being weighed. Instead of the levers being hung by clevises from a hook or bolt, fastened to the bottom of the corner irons, the pivot of the lever rests in a saddle (with steel facings) which is suspended by two loops, passing up through the corner iron and hung to a cross-bar ; this cross-bar rests on a friction point which allows the scale platform to swing from this point. The result attained by this device is that in driving on or off the scale, the whole platform swings upon the four friction points, which do not allow the platform to move or grind upon the knife edges of the levers, which are thereby kept from becoming dull and rendering the scale less sensitive.

Another feature is the manner of setting the platform pivots. These are inserted through the lever instead of being placed on the top. The platform bearings thus straddle the levers and are so formed as to make a housing for the pivots, so that they are protected from water running down upon them. The pivots of all large scales of this make are of wrought iron,

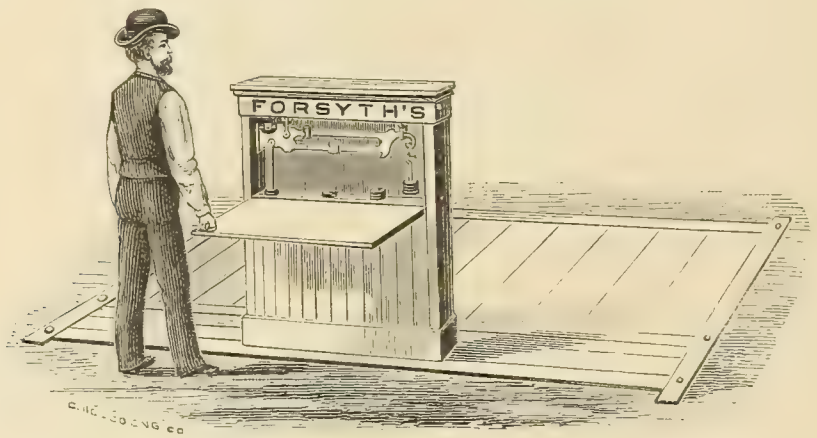


Fig. 326.—Pit Wagon Scale.

with square steel welded into the bearing edge. This manner of making the pivot enables them to be tempered to the utmost degree of hardness without impairing the strength of the pivot. The weighing beams of all wagon scales are made with a separate beam for deducting the tare or weight of wagon, leaving the net weight shown on the beam. The foregoing remarks apply particularly to pit scales or those having the working parts of the scale under the platform in a pit. Wagon scales of various sizes are are also made wherein all of the weighing machinery is hung above the platform, the platform being suspended to it by rods. The machinery, being overhead, is kept dry, and by the use of long rods to suspend the platform to the pivots, the knife-edges do not become worn by the motion of the platform in driving on or off the scale. These scales are adapted for use with a wagon dump for unloading wagons, as there is nothing below the platform to interfere with the swing of the dump, and the platform is sufficiently wide to allow the dump to be placed in the middle of the scale. While a dump can be used with pit scales, its position has to be arranged with a view of cleaning the under-hung levers, but in the suspension scale it

can be placed anywhere in the platform. The ordinary hopper, compound beam, packing, dormant and portable scales and railroad track scales, on the suspension and pit plans, are constructed on similar principles.

Grain Meter.—To make a barrel of flour without knowing how many bushels of wheat it took and how much of every item of manufacture it takes to a barrel, is simply carrying on business blindfold.

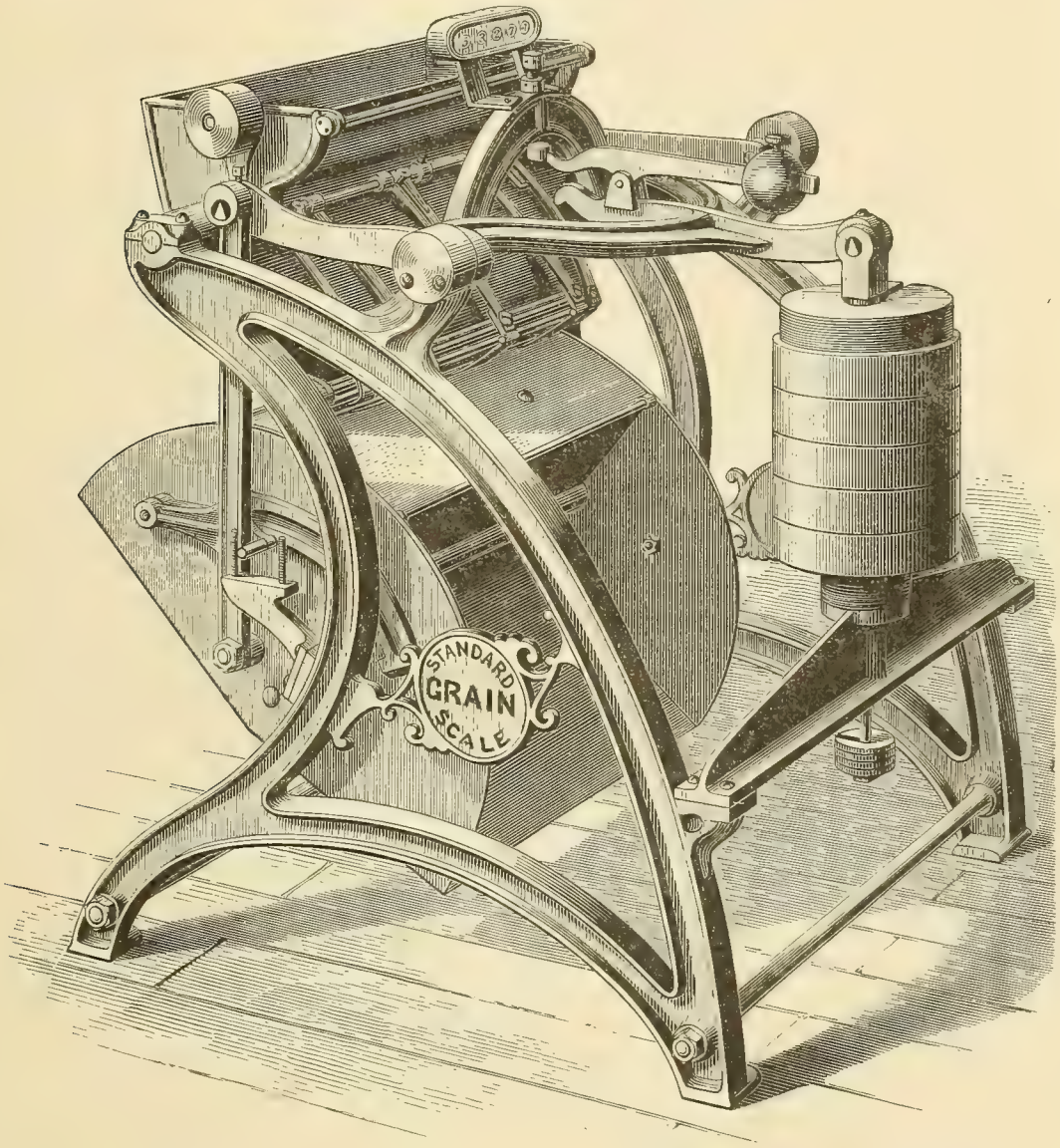


FIG. 327.

The Standard Automatic Scale* (Fig. 327), for the rapid and correct weighing of grain and flour, consists of a discharge bucket suspended from knife-edge pivot points of an even-balanced beam, and divided into two equal compartments.

Gravitating latches, pivoted to the suspenders hanging upon the knife-edge bearings, hold the bucket in position to receive the grain.

* Made by the Simpson & Gault Manufacturing Company, Cincinnati.

Suspended from the opposite end of the beam, by the usual clevis and hook, resting upon knife-edge pivots, are the balancing weights. The weights are so arranged that the large weight, in connection with the small one on the supplemental beam, balance the empty bucket and the grain weight, the grain to be taken in the bucket at each dump. Immediately above the grain bucket is a spout tapering to a long narrow opening at the lower end, which delivers the grain into the bucket; attached to the upper end of the spout is the spout from the elevator bin or cleaning machine. Two long narrow plates, closed by gravity, and working independent of the weighing mechanism, are loosely hung upon a small steel shaft on the front of the spout, and operated by means of fixed clutches. The larger one, which swings under the mouth of the spout, is called the main cut-off, the smaller one the supplemental cut-off. A grain-wiper on the lower mouth of the spout wipes off any grain resting upon the main cut-off each time it is withdrawn, and a similar wiper on the under side of the main cut-off performs a like service for the supplemental cut-off. Lifting links, attached to the scale-beam, rolls the shaft up and down as the beam rises and falls.

When the bucket has reached its highest point, the cut-off plates are withdrawn from the mouth of the spout.

When an amount of grain equal to the difference between the large and small weights has been received in the bucket, the bran and bucket descend until the small weight rests on the beam, and then receives an amount of grain equal to the small weight, and its downward movement is checked.

The main cut-off plate closes to its fullest extent, leaving a narrow opening through which grain, equal to the small weight, is allowed to slowly pass until the bucket is full, when the supplemental cut-off completely checks the further flow of grain; the bucket continues to descend until released by the clutches holding it in position, turns on its shaft, and the grain is discharged.

The buckets work alternately in this manner until the grain supplied to the scale is exhausted. The turning of the bucket on the shaft and the discharge of grain from the full compartment causes the empty compartment to come under the spout to be filled in turn.

The scale-beam of a machine weighing 100 bushels per hour rises and falls only one-half inch. The manufacturers of this machine claim that it will weigh and wear correctly for twenty years.

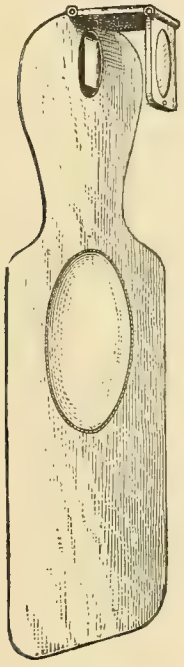
Two attachments, one called a "stop motion," the other "feed regulator," can be applied; one for causing the machine to stop work when any desired number of fillings have taken place, the other stopping the flow of grain when the stone, upon the top of which the machine is placed, ceases running. For the purpose of weighing the exact amount of flour in uniform quantities (196 pounds) for a barrel of flour, it is a great improvement over the old method of weighing the barrel before filling, and then adding to or taking therefrom.

Inspection of Flour and Meal.—"Good meal should feel smooth and not oily and clammy, sticking to the hand. If smooth, oily and sticky, it is too low ground and the stones dull. If part oily and part coarse and lumpy, and if it sticks to the hand, the stones have too much feed or are dull

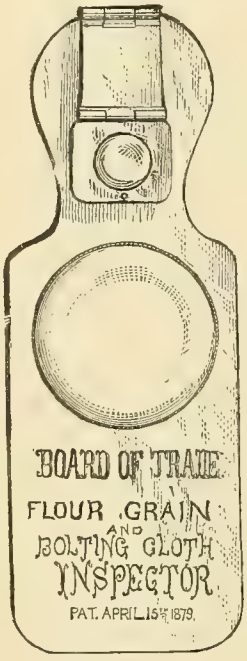
and badly faced, or some furrows have too much draft, and are too steep at the back edge. The bran should be springy and elastic after the meal is sifted out. If the hand be shut up quickly on a handful, there should be a large portion that escapes between the fingers. When the bran is stiff and the inside white, it shows that the stones are dull or overfed. If some of the parts are thicker than the rest, there are some furrows that have too much draft; are too deep and steep at the back edge; and the feed is too little. Inspection of flour should be made with plenty of light, and as far as practicable with the same degree of light, in order that the color may be more readily compared and judged."

The color of flour increases in whiteness in proportion as it is reduced more finely. (Kick.)

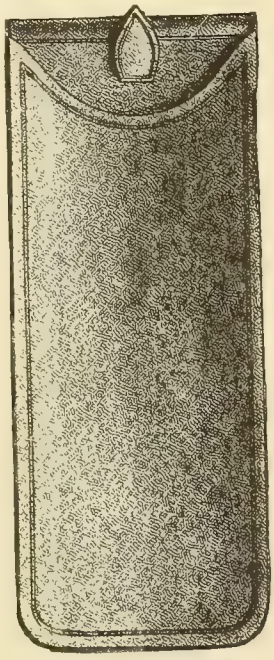
"Good flour should be white, with a slightly yellow cast. A bluish cast is a bad sign. There should be no black specks. On wetting and kneading it



Open.
FIG. 328.



Closed.
FIG. 329.



Case.
FIG. 330.

between the fingers it should work dry and elastic, not soft and sticky. Flour from spring wheat is apt to be sticky. On throwing a lump of dry flour against a dry, smooth perpendicular surface, it should adhere in a lump, not fall like powder. On squeezing some of it in the hand, it should retain the shape given it by the pressure."

A handy testing sieve is made of a tin box, 8 inches diameter and $3\frac{1}{2}$ inches deep, containing two taper rings, several rings between which the sieve cloth is placed, and by pushing one over the other the sieve is formed. There are nineteen changes of cloth, from No. 000 to No. 16 inclusive, contained in the case.

Fig. 328 shows a very compact and convenient flour trier and inspector, open; Fig. 329, the same thing closed; Fig. 330, the case.

In ordinary bread-making one barrel of 196 pounds of bakers' flour makes from 260 to 300 pounds of dough, being a gain of from 32.6 to 53 per cent. In the baking each pound of dough loses about one and three-quarter ounces, or eighteen pounds of dough lose about one and three-quarter pounds, which is nearly the same thing. This brings this percentage down to about 28.6 and 46.5 respectively.

Packing.—Foreign receivers object to the ordinary barrel as being likely to be short in contents through cooperage, sifting out, and so on. Flour in sacks stows closer and for this reason alone the freight is less than on barrels. Again, the barrel weighs 15 pounds for 196 pounds of flour and the sack only four to six.

Barrels should be of white oak, well seasoned. The moisture from green wood has a very bad effect upon the keeping powers of flour. Flour keeps better in a cool, dry, airy room than anywhere else. Exposure to hot sun or wet, or being stored too near corn or oats, which are liable to become heated, will injure the wheat.

Paper flour barrels are made from sheets of paper cemented together into a thick impervious sheet under an enormous pressure ; they are then pressed to shape and water-proofed, and, when finished, they weigh a little more than half as much as the wooden barrel. They may be shipped in very little space, 120 barrels may be stored in the place occupied by 100 wooden ones. They roll straight, are nearly air-tight, and are impervious to dampness, and bear transportation through any climate, and will transport in cars or holds of vessels, unaffected by any odor of turpentine, or any such materials. The loss of flour in wooden barrels from the West to the seaboard is by some stated at four to six pounds and the cooperage upon them in transportation and in store, five to ten cents each.

There are also barrels made from wood pulp. The body is in one piece, made from coarse wood pulp, under 400 pounds pressure per square inch. The heads are made in the same way.

It is a common cause of annoyance and loss of material that barrel hoops will not stay put. By expansion and contraction of the barrel they are either eternally becoming loose and flapping about the barrel like a big collar on a small dog, or being burst from the barrel, leaving it at the mercy of expressmen and hoisting machines. An inventive Yankee has conceived the idea of substituting for flat metal or wooden hoops those of corrugated iron wire ; the hoop consists of a corrugated iron wire hoop. The ends of the wire are fastened by twisting. It is claimed for this hoop—first, that it will continue tight and intact under circumstances in which ordinary hoops would have hung loose or burst ; the wire stretching and expanding with the expansion and contraction of the barrel ; second, that there is less metal or wood in contact with the staves, and therefore less moisture and less corrosion of the hoops. It is said that the twisted joint does not interfere with the barrel being rolled or handled in the usual way.

There is a growing demand for flour put up in sacks, and millers are paying more attention to this mode of shipment than formerly. Seamless cotton or jute flour sacks are manufactured, which have the advantage

that, besides being well and closely woven, they have no seams which can rip and discharge their contents.

Paper flour sacks are of familiar use These were brought into being by the exigencies of the war, and are now made in such large quantities that by far the greater part of the sack-flour trade is carried on through their medium. Arkell & Smiths, Canajoharie, N. Y., are large manufacturers of

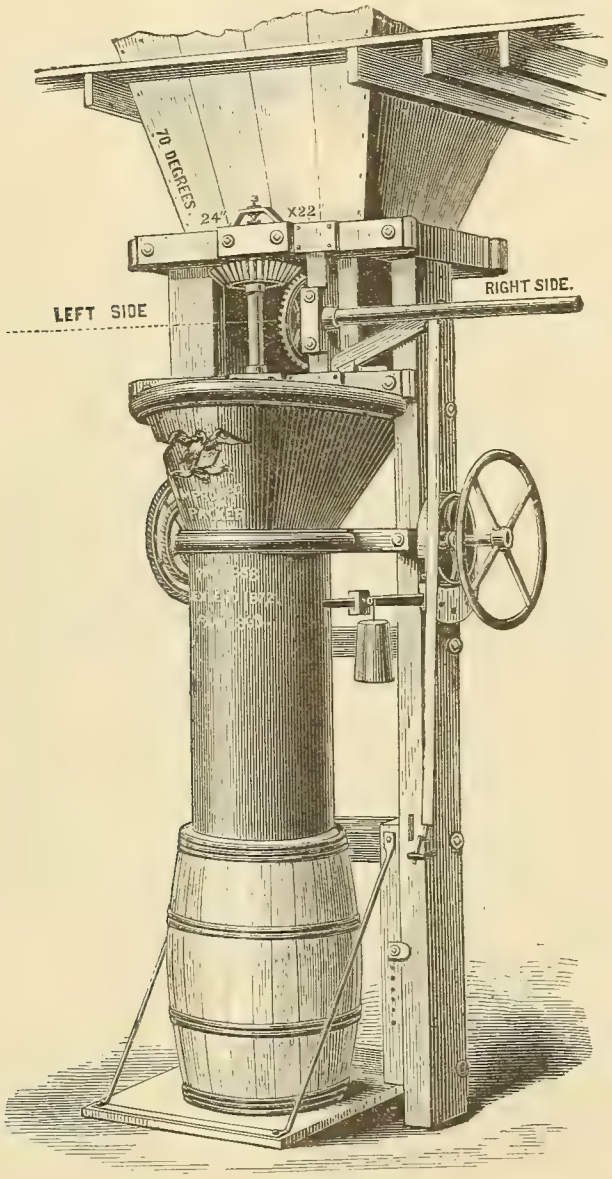


FIG. 331.

paper and cotton flour sacks, their factory having a capacity for producing 30,000,000 per year. These goods can be recommended.

Economic Flour Packer.—The improved Economic flour-packer, made by the Simpson & Gault Manufacturing Company, Cincinnati, packs in barrels or half barrels, and in bags of all sizes, whether of cloth or paper. It is of simple and durable construction, and is not liable to get out of order.

It can be set up easily and conveniently, and will pack direct from the bolt as well as from a garner or flour-chest. The machine is 8 feet 5 inches high, driving shaft 7 feet 7 inches from the floor, and occupying two feet square of ground. The setting up can be done within two days, without even stopping the mill. Fig. 331 shows a hopper or flour-chest, as it should be constructed, on the top of the packer, and a barrel on the platform. The platform with barrel on it is raised until the cylinder, now above the barrel, reaches its bottom. The driving shaft is then raised, throwing the machine into gear, and the packing process commences. The flour inside the cylinder is forced into the barrel. The speed is fixed in accordance with the amount of work the machine is required to perform. At sixty revolutions per minute, from forty to forty-five barrels may be packed per hour. The flour is packed without gushing through worm-holes, etc., a difficulty most of the old kind of packers are subject to. It packs equally tight, and as the barrel fills up the platform recedes, and when the desired quantity is packed, a button attached to the platform strikes a trigger which throws

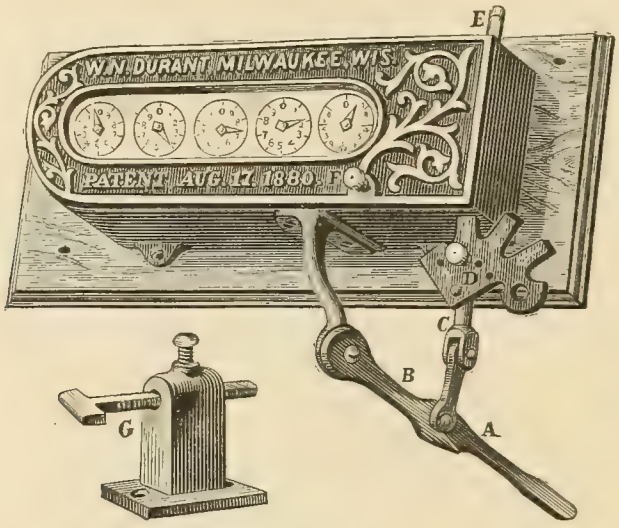


FIG. 332.

the machine out of gear. The barrel is then taken off, replaced by another, and the same process is repeated, as described. To change from barrel to bag, and reverse, the barrel cylinder and screw is taken off, and replaced by the intended size of each. The balance weight is changed, and everything else is the same as described when packing in barrels. The change of size requires only a few minutes' time. The machine will pack bags, according to the size and speed, in from three to four per minute.

Tallies.—Tallying devices for registering the quantity of material packed are almost indispensable in any well-regulated mill. They may be simple tallying counters showing to the packing hands at the packing machines the number of packages of output; or they may register this in the office, by means of electric connections. Each tally may be of two kinds—adjustable to various sizes of packages, or fixed to tally only one size.

Adjustable Tally.—The adjustable tally, Fig. 332, has the works inclosed in an iron case. The levers, A, B, and adjustable bolt, G, are the

attachments to the packer (the bolt, G, is secured to the platform of the packer), D is the gauge for adjusting the machine to tally eighths, quarters, halves or barrels; it is secured to rod C, and gives the rod a long stroke when barrels are packed, and a very short one in packing eighths. The knob, F, is used to throw the works out of gear, and prevent the machine from tallying when adjusting it from barrels to halves, quarters or eighths. The first dial to the right indicates the fraction of a barrel, and the other dials indicate the whole barrels.

The Electric Tally.—This tally, Fig. 333, is well made, finely finished, and nickel plated, and covered with a glass globe. It is placed in the office or wherever most convenient. For large mills, the several tallies are generally arranged under one globe. One battery will work a tally several hundred

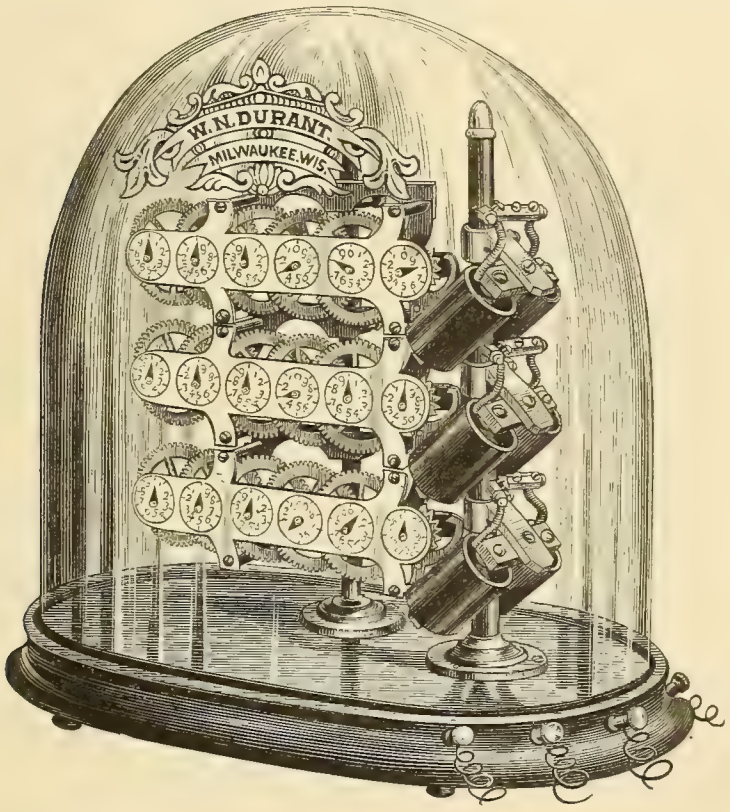


FIG. 333.

feet from the packer. The battery needs but little attention, and a few cents a year will keep it in working order. For a short distance the tally will be connected to the packer by two lines of wire, one line will go from the tally to the battery and one from the battery to the packer; the other will go direct from the tally to the packer. The attachment on the packer is to connect and disconnect, or *vice versa*, these lines once for each eighth of a barrel packed. When they are connected eight times in succession, a barrel is registered on the tally in the office; four times for a half-barrel, etc. If desired, the attachment on the packer can be inclosed in a box and locked up.

The adjustable and electric tallies register eighths, quarters and halves as well as barrels. The device for changing these machines to tally barrels or

fractional parts of a barrel is so simple that it takes but a few seconds to make the changes. They always give the total number in whole barrels, and when they have tallied up to their capacity they will set themselves and commence over again.

The "barrel tally" is made exactly like the adjustable tally, except that it is not adjustable to eighths, quarters or halves. It is made entirely of iron and brass, and warranted not to break or get out of order. It can easily be attached to packers, engines, skids, traps or anything else desired. It is largely used on bran packers to register the number of sacks packed out; the sacks being weighed and a definite amount of bran filled in each. In such a case a barrel tally will save a great amount of figuring, and time in taking a yield.

It is used in connection with flour packers only when barrels or packages of one size are packed.

The barrel tally is supplied with an attachment for connecting with the packer, whereby, as soon as it is secured to the packer, it is in working order. Three sizes are made as follows: No. 1, tallying 10,000; No. 2, 100,000; No. 3, 1,000,000. These tallies are made by W. N. Durant, Milwaukee, Wis.

The attachment for the packer accompanies each machine. When desired, a wooden box to cover the tally and attachment will be furnished. This box prevents strangers from meddling with the machine, and it also forms a guard around the connection. With these tallies you are able to see at a glance the exact number of barrels packed each day, month or year, and in taking a yield much time and trouble is saved. They can be attached and put in accurate working order in fifteen or twenty minutes.

By using an adjustable, electric, and in some cases only a barrel tally, a flour-book may be kept, which will be a positive check against any error. A tally will soon pay for itself, not only by preventing errors, but by its convenience and amount of time and labor it will save.

The cost of one of these tallies compared with the work it will do, is astonishingly small. For an adjustable tally the price being only $.0005 per barrel tallied for one year in a mill making 30,000 barrels.

The electric, adjustable and barrel tallies are warranted to tally accurately and with reasonable care to out-last the packer to which they are attached.

The principal advantages claimed for these tallies are: First, in registering in the office the amount of flour that is packed in the mill, and showing just when flour is being packed, and whether in eighths, quarters, halves or barrels; second, these tallies, in connection with a grain weigher, flour and feed packers form a complete system of registering, which can be carried out as follows: Electric tally No. 1 in the office registers the number of bushels of wheat being ground; tally No. 2, the flour packed out; tally No. 3, the feed. With such an arrangement, an accurate calculation of the yield can be made at almost any time. Third, when it is desired to keep the different grades or brands of flour separate, an electric switch is used, and each grade is registered on a different tally, or, in connection with a grain weigher, sev-

eral kinds of grain can be run through the same weigher, and each kind registered on a different tally.

Brands, Etc.—The barrel or package should be marked with the firm-name, place of manufacture, kind of wheat from which the flour was made, and the kind of flour—as low grade, wheat flour, straight, patent, etc. A perfect system of marking is thus required, and this is effected by proper brands and stencils, such as are made by S. D. Childs & Co., Chicago. Shipping receipts should indicate the character of the shipments, and conform to the marks on the bags or barrels. A series of rubber stamps, such as are made by S. Holderness & Co., Chicago, will be found useful for this purpose, or wherever a memorandum head is wanted.

Storage.—Flour stored in barrels does not keep as well as in bags, getting musty, sour and mouldy, the gluten becoming soluble. Lack of air circulation causes this, as proved by the fact that the innermost flour is the sourest.

Wheat should never be stored for any length of time; and then rehandling or turning it from time to time is necessary. Long storage darkens the color of the grain and the berry loses its dryness. Wheat requires air and light and should be given frequent handling.

Floors for storing flour must be strong, as the weight is extremely concentrated.

In the storeroom the wheat should not be deeper than two feet.

CHAPTER XXXVII.

CHANGING AND ALTERING MILLS.

Changing Dress, etc., for New Process—Altering Mills.

Changing Dress, etc., for New Process.—In changing from an old process to a new process burr milling, the first thing to be done is to change the dress of the burrs. Less land surface is needed for the new than for the old process, and we may lessen the land surface in two or three ways. One way is to sink a narrow furrow between each two of the old.

If the mill being changed is a two-run mill, we must use one run for wheat and one for middlings; and the middlings stone should have shallower furrows than that for wheat.

The wheat stone, if four feet, may run 130 revolutions or less, and the middlings stone 140 or less. This will generally necessitate a change in the gearing or pulleys, because ordinarily we will find both stones geared to run the same speed. If it is not convenient to make the two different, then both may be run at the same speed—say 132 revolutions. This may make a difference in the speed of the other machinery; but it will not be likely to make much, except in the bolts.

Suppose it be intended to change a stone mill to the roller system gradually, instead of making all the change at once. The first thing to do in the ordinary-sized mill will be to put in one set of smooth rolls and one set of bran rolls and to grind a little higher than usual. One set of 9 by 30 rolls will take care of the bran in a 150-barrel mill supposing that the grinding is medium high. One set of 9 by 30 smooth rolls will take care of all the germ and coarse middlings in the same mill. The next time that a change is made either the same year or another season, a full set of reduction rolls must be put in (less, of course, the one set of bran rolls already in). There must be also one more set of smooth rolls and more purifier capacity. Then, if the bolting were arranged properly before, there would be needed only one or two changes in the cloths. If the bolting were not properly arranged before the change to the roller system, it would be absolutely necessary to change to modern methods. The cost of the first change, the addition of the smooth and bran rolls would be $450 (less 5 per cent.) for the bran rolls, and $350 (less 5 per cent.) for the smooth. The setting up of these two sets of rolls should not cost over $75. It will be necessary to have one reel about ten feet long clothed with No. 8 or No. 9 cloth, costing say $60 to $100. The second year the five more sets (if for winter wheat) and one smooth set would cost for the machines $2,500 (less 5 per cent.), and the setting up extra. In putting in the bran rolls and smooth rolls it should be with the

intention of adding the others later on. The shafting can be arranged for this, either on the other side of the mill, or driving from above, so as in neither case to interfere with the shafting of the stone.

Altering Mills.—Brown gives an account of a three-run mill in Pennsylvania that he altered from old to new process:

"The wheat-cleaning machinery of this mill consisted of one old-fashioned separation and a rolling screen. It had two run of four-foot stone for grinding wheat and one for corn. Its bolts consisted of four reels in one chest, two on each side. There was a bran duster in the mill, and this summed up the entire machinery of the mill for making flour. Years ago it used to run night and day, turning out a grade of flour that gave good satisfaction, and selling all the flour it could make at the mill door. When I arrived at the mill it was not running, and had not been for three months, the complaint being that the flour could not be sold, and if sold it was almost sure to come back. The first question asked was, 'Can you help us out?' I thought I could, and we went to work. I immediately ordered a three-foot run of stone on which to grind middlings, a good smutter and brush machine to clean the wheat, new bolting cloths and a first-class purifier. I got the millwright to work making necessary changes, and had the millers take up the stone, and I assure you there was plenty of work for them to do. I inquired for the furrow and land sticks, and the board for the eye with draft circle on. The boss miller hunted around for awhile, and finally brought me some furrow sticks, saying that he believed they did not have anything else, at least he had never used anything further. Well, these furrow sticks were 1¼ inch wide, and the stone had forty furrows. I made new furrow sticks two inches wide, land sticks to correspond, and fitted a board in the eye describing draft circle on it, one inch to the foot. I described another circle around the skirt of the stone about an inch from the edge, spaced off the sections, and then laid on my furrow sticks. When I found that the draft on those stones had always been calculated from the back edge of the furrow; but at that, even, some furrows had a half inch more, and some a half inch less draft. The proportion of furrows to face was about equal. If either was greater than the other it was the face; and a great deal of the face was in or near the eye. This, of course, gave a better opportunity to get the stone in proper shape than if the amount of face in the eye had been less after properly laying out the stone and getting the millers to work. I looked after the rest of the work in detail, and in a very short time we had the mill running with the following arrangement:

"The wheat passed through the roller screen, thence to the separator, next to the smutter and brush machine—these last two being adjustable so that the wheat could be cleaned as desired—and then passed on to the stone. The stones, as remarked before, were two run of four-foot burrs, with the coil spring on the spindles, and running at a rate of 140 revolutions per minute. They had each forty furrows two inches wide, were medium close, and calculated to grind from six to eight bushels per hour. The chop from both run of stone was carried to the upper reel of the chest, on one side covered with six feet of No. 10 XX cloth, and the balance with No. 11 X, the reels

being twenty feet long. After the flour was cut off, all went to the reel below covered with six feet of No. 12 X, ten feet of No. 13 and four feet of No. 1 cloth. Flour was also taken from this reel, and the remainder, with the exception of the bran which went over the end of the reel, passed to the upper reel on the other side, together with the chop from the middlings stone. This reel was covered with six feet of No. 12 X, ten feet of No. 14 and four feet No. 2 cloth. Flour was taken from this reel also, and the returns were returned to this reel. The middlings from the No. 2 cloth went to the reel below covered with No. 12 X cloth throughout, the dust being returned to the reel above, and the middlings going over the end of the reel to a first-class purifier covered generally, with Nos. 9, 6, 5, 3 and 1 cloth. The middlings all ran together (except No. 1) to the three-foot stone to be reground, and then to the bolt covered with Nos. 12 and 14 cloth, already mentioned. It will be observed that this mill makes only one grade of flour, which gives good satisfaction, and at present the proprietors are unable to fill all their orders, and are making a handsome profit. It will also be observed that while their bolting capacity is limited, they dust their middlings well, grind them separately, and are thus enabled to make a good straight grade of flour.

"Since the above was written, I have had an opportunity of revisiting this mill, and of making some further improvements. With my advice they have added another run of stone, another reel twenty feet long and another purifier, same make. They are now bolting their middlings flour separately, which enables them to make a straight grade or patent flour, as they may desire, and is a much more satisfactory arrangement.

"I was also informed by the proprietors that in running their mill eight months after it was repaired, they made a clear profit of $8,000 above all expenses, repairs included.

"Take a mill with two run of stone four feet in diameter, for wheat. This mill has two, and perhaps three reels, each twenty feet long. For the sake of being definite, let us presume that it has three reels, all in one chest, but that two are side by side, and one below and between the other two, each being independent of the other. Each run of stone has an elevator, and each elevator carries to a reel. The chop is thus divided between the two upper reels, which, if winter wheat is ground, are probably covered with Nos. 12 and 13 cloth in equal proportions; and the lower reel probably has on six feet of No. 12, six feet of No. 9, four feet of No. 6, and thirty inches of No. 4, with No. 00 on the remainder, arranged in the above order from head to tail. This is called the return reel, and bran, with all else except the flour that is taken out of the two reels above, goes into this reel.

"We will first take up a stone and commence reducing the face. No doubt the stone has as much land as furrow surface. Now, widen three furrows one-fourth of an inch each, on four sides of the bed-stone, making twelve furrows in all, and leave them true and smooth. Dress the face of the runner sufficient to keep it in face and put it down to work. Take up the other stone and dress the furrows in the runner and the face of the bed-stone, the same as in the first run. The next time the first stone is taken up reverse the order of work, furrowing the runner and dressing the face of

the bed-stone, alternating in this manner through the year, and your stone will be in better order than by dressing the furrows once a year. After the furrows have been once gone over all around, it will not take so long to dress the stone afterward. In changing the dress of a stone in this way you do not take the stone off from its work any longer than for the usual time for dressing; and after once going around on all the furrows, if you are satisfied that you have improved them, and think they have too much face, as they undoubtedly will have, you can make new and wider furrow sticks and go over them again.

"We will now change the spout from one run of stone, so as to run the chop from both run into one set of elevators and into one reel. We will clothe this reel with eight feet of No. 10 XX, and the remainder of it with No. 12 X cloth, and the lower or second reel with eight feet of No. 13, eight feet of No. 14, and four feet of No. 1 cloth. After cutting off the flour from the first reel, run the balance to the second reel, and taking off flour from this reel also, so far as it is good, you will get all your middlings through the No. 1 cloth, and the bran will pass over the end of the reel. You will now need a short set of elevators to carry the middlings from the lower to the upper reel on the other side, here to be dusted, ready for the purifier. Cover this reel with ten feet of No. 12 and ten feet of No. 13 cloth. The dust from this reel should be returned to the lower reel, not to the chop, and all returns, from whatever source, should go to this same reel and never be made to the chop, or first reel. The object of returning is to remove the specks, and the returns are usually made from a finer cloth than that at the head of the first reel; and in putting material that has passed through a No. 12 or No. 14 cloth back upon a No. 10 cloth, one can readily perceive the liability of getting specks. By throwing the returns into a fine cloth you are not so liable to get them; and another reason for this is, that the proportion of fine and coarse material is about right as it leaves the stone, and to put the returns with it changes the proportion. The proportion has been changed, moreover, in the second reel, and there is need of all the fine material available to make it bolt properly. By proceeding in this manner, the first and second reels can be used for flour, and the third reel for finishing up on, or dusting the middlings. The middlings ought to go to two purifiers, the one following the other, but as we do not possess much money we will use only one. This is the first piece of new machinery we have had to buy, so we will get a first-class machine—one that has been thoroughly tested and is known to be a good one, and to have plenty of capacity to do the work. If you buy from an agent and he tells you that you need a machine to clean one hundred pounds per hour, purchase one large enough to clean two hundred per hour. It is a great mistake in buying purifiers to endeavor to get cheap ones, thus obtaining machines that are too small. If you are able to get two machines instead of one, it is economy to do so. All do not see it so at first, but are compelled to acknowledge it sooner or later.

"After your middlings are well purified, they are, of course, ready to be ground, and ought to be ground on a stone dressed and kept for that purpose. But, for the present, and in order to economize, we will run them to the eye

of one of the wheat stones and grind them there. This is not the proper way to do it, but as we have no other stone, no money, and are intending to make only a straight grade, we will allow you do so until you see the benefits of this much of the new process. Of course, in grinding the middlings in this way, they must be bolted with the chop also, which is not right.

"But when you have seen the result of your mill so far improved, and think you would like to take a step farther in advance, procure the best close old stock three-foot upper-runner you can find, and put it in a strong husk frame. Dress it as nicely and smoothly as possible, taking all the pains you are capable of, using the same kind of dress as in your wheat stone, and dressing it in the same way, with this exception : do not have the furrows so deep. Take great pains to have it level, in true face, in perfect tram, in both standing and running balance, and do not run it to exceed 140 revolutions per minute. Use the spare set of elevators you had left after making the change before mentioned, and if you do not feel able to add to your bolting capacity, run the meal from the middlings stone to the second or lower reel to be bolted there. This will be more satisfactory than before. When you are prepared to increase your bolting capacity, put up a single reel twenty feet long, or two reels twelve feet long, using Nos. 12 and 13 cloth.

"By the time you have progressed this far along, you have got your stone dressed so that you are making more middlings, and need another purifier to follow the first one. You are granulating your wheat and middlings separately ; you are bolting separately, and making two grades of flour, the poorest better than the best you ever made before, and are prepared to take off five, ten, fifteen, twenty, twenty-five or perhaps more barrels of patent flour from your middlings bolt, mixing the remainder with your first run in a conveyor for that purpose, or, if you wish to make only a straight grade, run the whole product of flour from your middlings bolt into the conveyor and mix with the first run."

CHAPTER XXXVIII.

MILLWRIGHTING.

Tools—How to Treat and Use a File—Marking Off—Timber Joints—Halving Together—Open Mortise and Tenon Joints—Regular Mortise and Tenon Joint—Blind Mortise and Tenon Joint—Dowel Joint—Various Methods of Setting the Bevels of a Hopper—Building an Overshot Wheel.

Tools.—We will lay down a list of tools for millwrighting work, giving the kinds and sizes most needed in every-day work. Of course there will be some special cases where extra large or extra small tools will be needed, as well as other tools than those laid down; but the following list is believed to be about right: There will be needed a common axe, for roughing out logs, and a broad axe and an adze for dressing them; an adze, a set of planes, embracing a jack and fore plane, smoother, and a "nigger shin," a tool little if at all used by carpenters. Its function is to work out curved surfaces, as segments of water-wheels, etc. It is about as long as a smoothing plane, and it might be made from that tool. For chisels, there would be needed a set of firmers, which may contain as many as fifteen sizes, of which about eight will be needed in every-day work, these being 2-inch, $1\frac{3}{4}$, $1\frac{1}{4}$, 1, $\frac{3}{4}$, $\frac{1}{2}$ and $\frac{1}{4}$. There must be some large framing chisels, running by half inches from 3 inches to 1 inch inclusive. There must be a brace and set of auger bits of sizes from $1\frac{1}{2}$ inches down to $\frac{1}{4}$ inch inclusive, and some bits for screws. There will be required a set of augers from $\frac{3}{8}$ up to 2 inches inclusive, and a 14-inch monkey wrench. Two screwdrivers will be enough, one 12 and one 16 inches long. There must be a good tri-square and a 24-inch graduated iron square, also a 12-inch adjustable bevel square. For marking out, there must be a scribing awl and a chalk line. Get a hickory mallet for use with the chisels; lignum-vitæ is too hard. This mallet should weigh about $1\frac{1}{2}$ pounds, and be in dimensions about $6 \times 3 \times 4$ inches, having its sides nearly parallel and the top wider than the bottom. There must be one hammer $1\frac{1}{2}$ pounds weight, with one end round and the other flat; and a claw hammer (about No. 8) weighing three-quarters of a pound or less. There might be a hand axe with a face 6 inches long and a handle 14 inches long. For a level, one 24 inches long will be right size, and there should be a small level to use in connection with the iron square. There must be a pair of "trams" to draw large circles, and a pair of 6-inch compasses; also one pair of 12-inch and one of 16-inch. This last will strike a circle thirty-two inches in diameter, and anything larger than that the trams will lay out. There should be a good plumb-bob, having the top of the bob screw out, as this kind centres the line better than the others. In the way of saws, there should be a 14-inch back saw, a regular 42-inch rip saw, a cross-cut of the same length, and a

14-inch compass saw. To sharpen these there will have to be a 3½-inch saw file for the back and compass saws, a 4-inch saw file for the cross-cut and a 5-inch for the rip. Bear in mind that a three-cornered machine file and a saw file are very different. I omitted mention of a lighter hammer for key seating, and weighing say three-quarters of a pound. In the way of cold chisels there should be all sizes from ¼ inch to 1 inch. There must be two wood files, one coarse and the other fine cut, of lengths 14 and 12 inches. There should be two flat files of the same sizes, and coarse and fine, for iron work.

There will be required gouges from ¼ inch to 1½ inches inclusive. One of the most useful things that the millwright can have is a slide rule, by which so many constructions and calculations can be made. Of course, there must be common and lumber pencils, and the regular "four-fold" two-foot rule. Then there must be provided suitable bench, carpenter's vise, machinist's chipping vise (which will answer for filing also), and sawing trestles.

How to Treat and Use a File.—"Probably with all the improvements in planers, milling machines and similar tools, and with all the increasing uses of the grindstone and emery wheel, the time will never come when the file will cease to hold a prominent position in the machine shop. It is always ready for use, always handy, is adapted to a great range of work, and is essentially a hand tool, responding instantly to the demand of the workman. It requires enough skill in its use to justify a proper pride in the workman who can do a good vise job. It is important, therefore, that the apprentice should early be taught the proper care as well as the proper use of the file. There is no surer indication of the sloven in the shop than a disorderly array of files on the bench.

Files ought to be properly handled. A chisel handle is not a file handle, nor is a pine stick, nor a section of a broom handle. The handle should be proportioned in size to the size of the file and the description of the file. A twelve-inch bastard file ought to have a larger or at least a longer handle than a twelve-inch finishing file. A slender square or rat-tail file should have a smaller handle than a coarse or large file of the same length, because the feeling in the hand when grasping the handle suggests or impels the degree or force used in the act of filing. With a small handle, the work man has a suggestion of delicacy in using. The handle should never be driven up to the end of the shank; that is, the shank should remain out of the handle half an inch, or thereabout. The handle should not be driven on the shank by blows on the end, the file resting on the bench or vise, either with a hammer or mallet. The handle should not be marred out of shape, nor defaced by bruises; such imperfections or injuries are repellant to the feeling of the hand. Bore the tang hole with a gimlet, and slightly ream the hole with a taper reamer; enter the tang enough to hold it, turn the file handle down, and, while having hold of the handle, rap it two or three times on the bench. There may be occasions when a blow or two from the hammer may be necessary to fix the handle securely. If so, hold the file by the handle, the file downward, and rap with the hammer on the end of the handle, but be careful not to mar the handle. See to it that the handle is in line with

the file, and not at an angle. It may be easy to file with the handle rising at a slight angle, but when the other face of the file is used the downward angle is anything but pleasant. Good work cannot be done with the handle and file out of line.

It is a good plan to keep the handles of the files off the bench. To do this, fix a narrow rib of wood on the top of the bench, far enough from the edge to receive the file near the tang and not allow the handle to project beyond the edge of the bench. If the strip is half an inch high it is enough, as it is only necessary to keep the files from the bench, so as not to get filings or other matter on the handles, and to enable the hand to pick them up readily. Some use a wire instead of a rib ; wood is preferable. It is a still better custom to have a board, twelve by fourteen inches, with the rib tacked on one edge or end, to place on the bench, at the right hand of the vise, to receive the files, and to be removable. It is well to have the bench drawer arranged to receive this file platform, with its files, at the close of the day's work, or to have cleats under the bench to receive it as a shelf or drawer. It is abusive to files to pick them up, one by one, or in a bunch, and dump them, rattling and scratching, helter skelter, into a drawer, on top of cold chisels, centre punches, &c. Besides this orderly arrangement of files, ready for use, is a great convenience, and the board or tray can be kept much cleaner than is possible to keep a bench, and may be replaced readily, if broken. It should be of soft, clear pine, planed smoothly.

The practice of heating the shank of a file, and using it to burn its way into the handle, is not only slovenly, but is wasteful. This heating destroys the tenacity of the wood, and the handle soon splits ; and a split file handle is good for nothing except kindling. Never mend a file handle ; it is even more useless than to mend rubber shoes or boots. Soon as a file handle cracks, throw it away. Wire-wound or string-tied file handles are an abomination.

About handling the file—working with it—few textual directions can be of use. It may be said, however, that the file is essentially a cutting tool, not a mere abrader. The action of filing is not a mere swinging of the arms with a file held suspended in the hands ; neither is it a rubbing motion, as with an emery stick. While the particles of emery present angles in every direction, the file has well defined teeth intended to cut but one way. The forward motion of the file is the working motion ; the backward motion is merely a recovery for another stroke. But to draw a file straight is an art only to be aquired by practice ; and this practice is absolutely required if the apprentice is ambitious to become anything but a botch. His hands also must feel the file during the entire stroke ; any lodgment of particles in the teeth must be instantly detected, and the obstacle removed, or a deep scratch is the result. In draw-filing there is still more necessity for patient practice. To the ignorant looker-on, nothing is simpler or easier than draw-filing ; in fact, no use of the file is more difficult to acquire. Either the right or the left hand will push the faster, to the ruin of the surface. The lines in draw-filing must be parallel, and in the direction of the job or piece. It will not do to have a "catty-cornered" finish or a "cross hatcheling" on a draw-filed finish. In

this parallelism of the lines and their uniformity consists the beauty of this finish—a finish never yet equaled by any polishing wheel or hand rubbing with abrading substances. It is the perfection of workmanlike finish. A high polish may delight the unmechanical eye, but the draw-file finish is a satisfaction to the mechanical taste."—*Boston Journal of Commerce.*

Marking Off.—Even in so small things as using a chalk line to mark off witness lines there is a right way and a wrong way to go to work. It is desirable to make a quick job, a neat job, and to preserve the line of the chalk.

The chalk line is a small, strong cord, well twisted, which, after being well chalked, is tightly stretched between two points and "snapped," so as to leave a straight, well-defined chalk line by which to work. The chalk should be really the shape of a wooden bung, the flat side only used. The line has a loop at one end through which an awl is passed, the awl being stuck exactly in one of the places between which the chalked line is to be made. The line being tightly drawn with the thumb and finger of the left hand, the chalk is held in the right hand, and the line bent on the chalk, keeping the flat side of the chalk parallel to the plane in which the cord lies, and a step being worn off that flat side in a regular curve, so that after several rubbings the entire surface of the flat side of the chalk has been worn away to a definite depth, when the operation may be performed in the same way. The sketch (Fig. 334) shows the proper section of the chalk when about half worn across. By this method the entire length of the line will be properly chalked, neither too much nor too little, and the chalk will not be wasted. Having chalked the line, stretch it tightly so that it will cover (not merely lie alongside of) the other point. The line being placed against the board or timber, near its end, with the left thumb, it may be drawn tight with the left fingers.

One eye being shut and the other placed above the line, this last should be grasped with the right thumb and forefinger about a foot from the left thumb, and the little finger of the right being placed upon the board to steady the hand, raise the line vertically and then let it go. If the line does not sight straight when raised, it has not been raised vertically and will not make a straight line.

In some cases it is more convenient to stand at the side of the board, in which case the left hand and eye are to be used as before, and the line grasped with the right forefinger and thumb, with the right palm down and the backs of the fingers to the front, the surface of contact of the thumb and forefinger being kept vertical and parallel to both straight portions of the line, it should be snapped as before.

To make a crooked chalk mark with the line, stretch the line between the two points as before, but when raising the line carry it to right or left as desired, and let go.

In some instances it is not convenient to use the regular marking tool, or very accurate work is not needed. In such a case, to mark a line upon a board or timber, parallel to the edge, and at some given distance from this edge, the ordinary two-foot rule may be used, being grasped with the left

hand, and rested upon the board, its length square with the edge, and the end at the desired distance from the edge. Then pressing the rule upon the surface of the wood with the left thumb, and resting the left forefinger against the edge of the board, the second finger of the right hand being placed upon the board and against the end of the rule. The scriber or

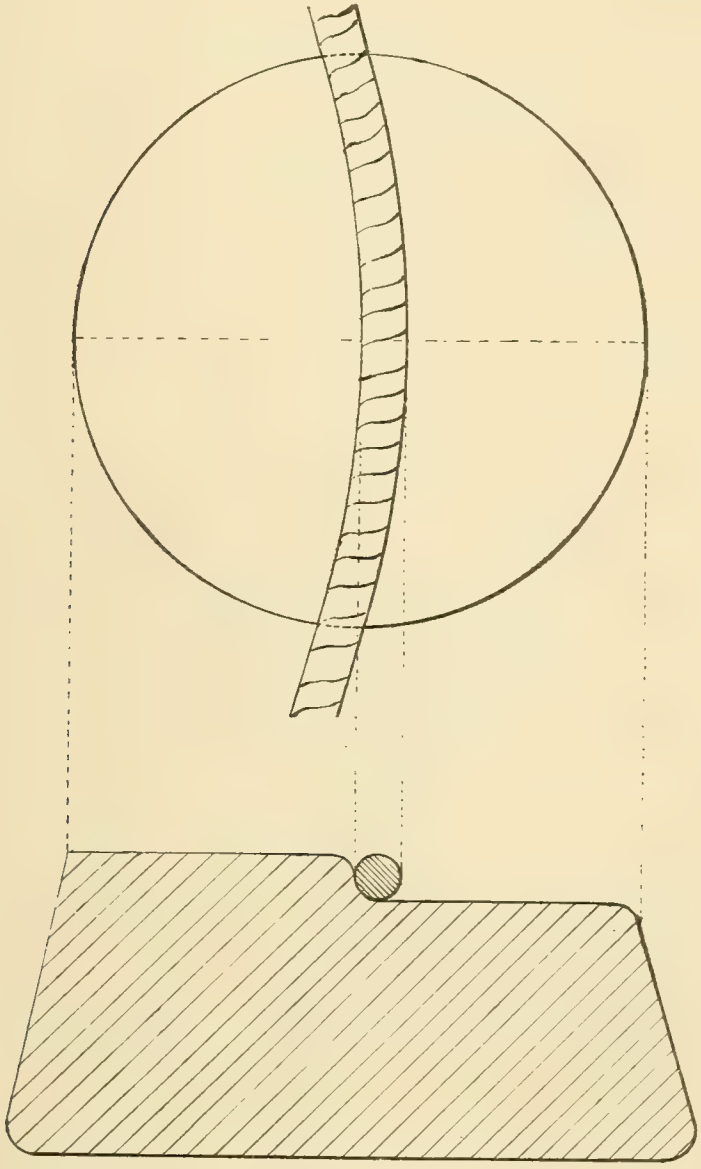


FIG. 334.

other pencil should touch the end of the rule, the second finger on the surface of the wood; then sliding the marking tool and the rule along the surface, the line will be at the desired distance, and parallel with the edge of the board or timber.

Timber Joints.—The following paragraphs give detailed directions for making in the best manner the more important timber joints, large or

small. Where the instructions refer to placing the pieces in a vise, of course this will be understood as applying to small pieces only, for light joinery.

Halving Together.—We will suppose that two sticks are to be halved together at their ends. We will consider that they have been dressed to dimension; the first thing is lining out. The tri-square is to be placed upon one of the timbers, with its beam resting along its one surface, the tongue upon the top, and the edge a little less than the width of the other stick, from the end of the stick being marked (Fig. 335). We had better call one stick A, and the other B; and suppose that we are marking A first. Place B right side up, upon A, with one long lower edge touching the edge of the square, and its end flush with the vertical side of A; slide the tri-square together along the top of A, until the vertical side of B is flush with the end of A. Take off B, and then, with a sharp knife line across A, at the edge of the square, running this line half way down each of the long

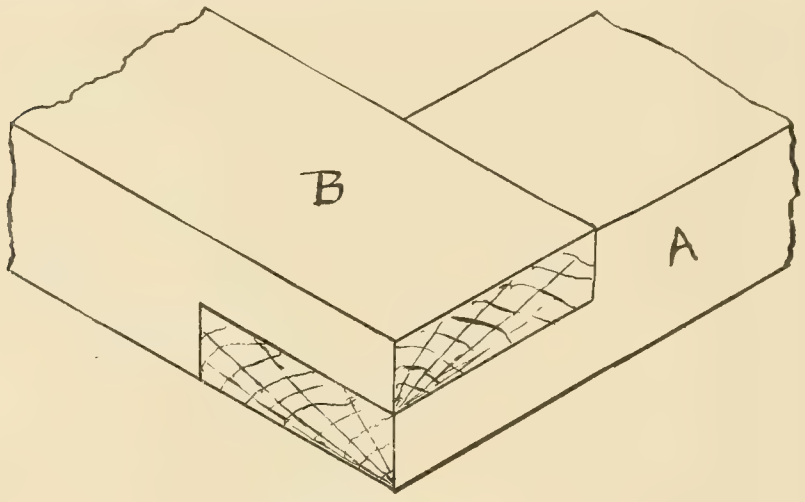


Fig. 335.—Halving Together.

vertical sides of A. Make smaller lines upon the lower side of the long vertical side of B, using the upper side of A as a measure, and turning the tops of both pieces down to draw the lines easily. Then, with the gauge, having the spur set to mark a distance from the head equal to half the common height of the timbers, guide the gauge head by the upper surface of each timber in turn, gauging along the long vertical side of each. To saw across, put each beam in turn in the mitre box, or in the bench vise, or against the bench hook. Use a fine-tooth back saw, taking care not to remove any of the knife-marks

There are three methods of taking out the wood between the marks. One is to put each stick upon its side and fasten it with a wooden hand-screw to a board upon the bench, then split off chips, parallel with the grain, with a paring chisel wider than the cut to be made, inclining the tool so that the chips shall grow finer as the tool cuts deeper, and giving it so much inclination that the chips shall not split below the three gauge-marks. After the last cut agrees with the upper gauge-mark, turn the stick and repeat the operation. There will then be a ridge running lengthwise of the stick. The

outer end of this ridge may be taken out with a wide chisel; then, turning the stick again and fastening it as before, take a narrow paring chisel and bevel the inner end of the ridge so that it will end in a straight line joining the corners of the knife-marks and the gauge-marks. There will then be a pyramidal ridge, which may be nearly all split off, and the rest pared off.

Another way is to place each stick upright in the vise and cut along the gauge-marks with a sharp, medium fine rip saw, almost to the cut made by the back saw, paring the surfaces with a chisel to finish, or paring the wider surface with a small plane.

Another method, with the stick upright, is to cut with a fine rip saw close to the gauge-marks, down to the back-saw cut, and square out the corner with a narrow paring chisel.

Another way, which will answer in some cases, is to lay the two ends that are to be halved together, holding them firmly together, and then, having

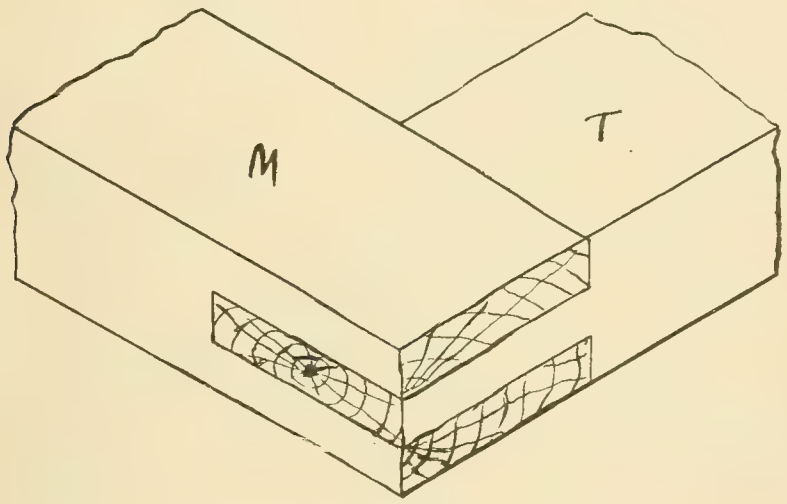


FIG. 336.—OPEN SINGLE MORTISE AND TENON.

scribed off on the side of one of them a square or a four-sided figure corresponding to the end of one timber, and having divided these in half parallel with the length of the stick, and having scribed off the lines upon the ends of the timbers, take a fine rip saw and cut down clear to the depth of the scribed figure on the side, and then, with a fine crossing saw, cut from one side of the two timbers down to the cross line. This will make the two timber ends just alike, each one having one half removed, and the two halves fitting together.

Open Mortise and Tenon Joints. (Figs. 336 and 337).—One of the sticks will contain the mortise and the other the tenon; we will call the first M and the second T. The first thing is to line out the mortise. Mark the length by laying the tri-square and the tenon stick upon it, marking each edge on the top of M with a sharp knife. (Knife-marks are the best for several reasons: they do not rub out, they can be made close and true to the edge of the square, and they have no appreciable width.) Then, resting the beam of the tri-square upon the top of M, and with the edge of the

blade at each of the points in turn, mark on the sides of M the place for the end of the mortise, making these knife-marks larger than the ends of the mortise. The length of the tenon is got by laying the tri-square and the mortise stick upon it, then lining across the top of T, then resting the beam

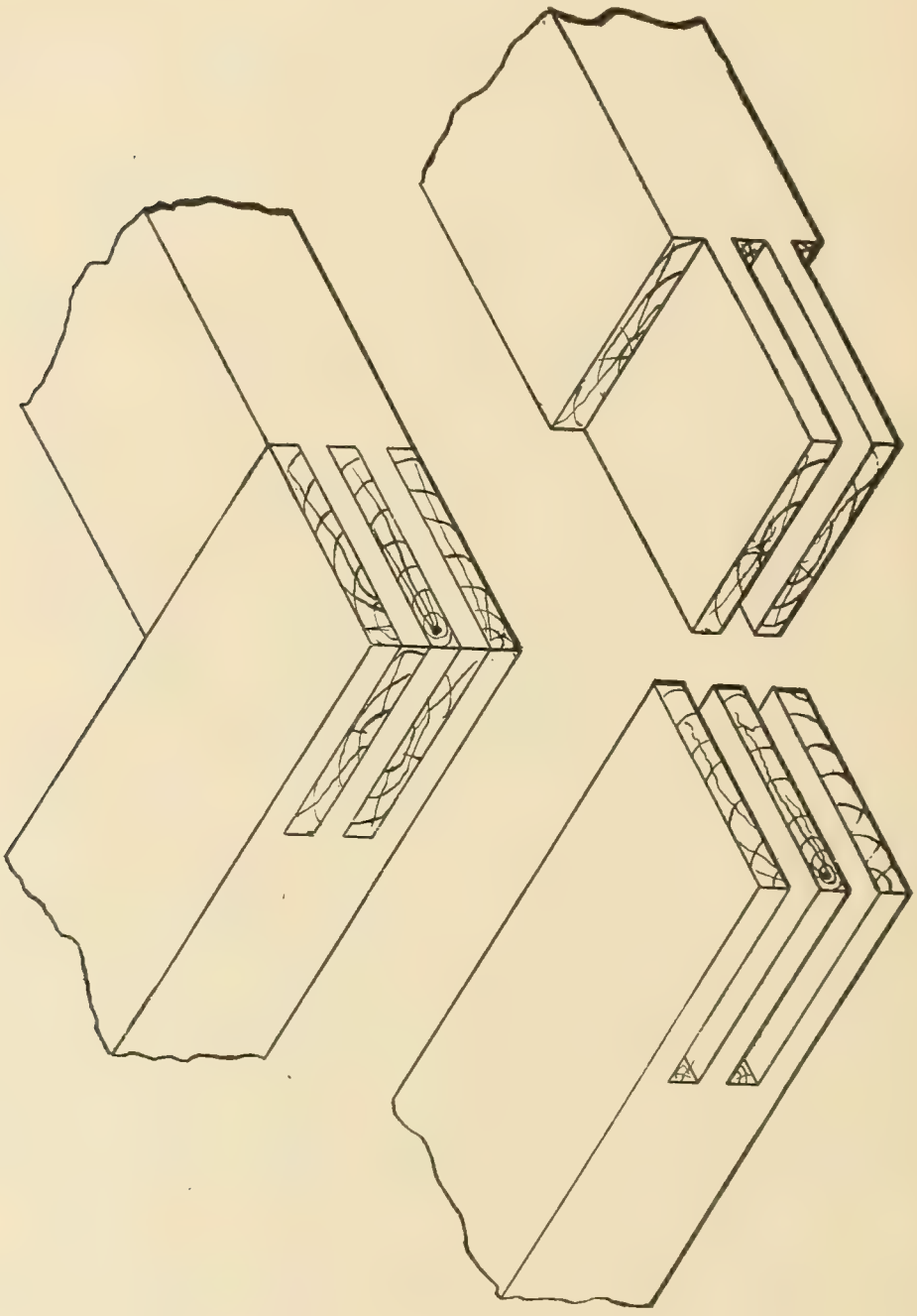


FIG. 337.—OPEN DOUBLE MORTISE AND TENON.

of the square on T, laying down both sides from the ends of the lines of the top, making a straight mark across the beam, and the stick will then have been lined all the way around. Then, setting the gauge spur one-third of the thickness of the piece, rest the gauge head upon the top of M and T in turn, gauging along the sides as far as the cross line before drawn. Next

gauge across both ends of the flush pieces. Then, moving the gauge spur back to two-thirds the thickness of the piece, gauge along the sides and across the ends of both pieces near the other gauge line.

We now have both the tenon and the mortise marked out. To cut the tenon a fine-toothed saw may be used. Cut nearly to the line, and make the surfaces true by a paring chisel; or a mallet and a chisel may be used entirely.

There are five ways of roughing out the mortise: 1. The stick may be placed upon the bench, side up, and fastened with a wooden hand-screw. Then, with a mortising chisel one-eighth inch narrower than the mortise is thick, placing the cutting edge centrally to the thickness of the mortise, and about one-fourth of an inch from the end of the mortise, holding its straight face upright, and next the flush end of the mortise, and being careful not to tip it sidewise, drive it in with the mallet. Cut half down through the depth of the stick. You will find that the chips and the chisels will work out easily from the open end of the mortise. Each cut should be taken nearer to the blind end. You must not cut closer than one-eighth of an inch to the blind end of the mortise in this roughing out. Then turn the stick over, the other side up, and do the same thing, ending as before, about one-eighth of an inch from the blind end. Then, turning the chisel so that the bevel face is next to the flush end of the mortise—that is, the straight face of the chisel next to the blind end of the mortise, and, holding the tool vertically, trim nearly to the end of the mortise.

2. The second way of roughing out the mortise is to take a medium fine saw and, placing the stick end up in the vise, saw nearly but not entirely down to the gauge-marks, being careful not to cut into them at side or bottom. The wood between the saw kerfs should be taken out with a narrow mortising chisel.

3. Use a bit of a diameter slightly less than the thickness of the mortise, and bore all the way through, beginning near the open end and working back to the blind end.

4. Take the bit last mentioned and bore one hole all the way through the mortise, near the blind end, taking the rest of the wood out by two saw cuts lengthwise.

5. With the stick upright in the vise, saw out the stuff close down alongside of the marks and very near to the blind end, then take out most of the wood with a narrow mortising chisel.

To finish, after any one of the first four methods, take a paring chisel as wide as the mortising chisel, and square out the blind end and bevel the sides to end in a line joining the corners where the knife-marks and the gauge-marks meet. Then take a wide paring chisel and bevel the sides of the outer edge until the bevels end in the gauge-marks, then split and pare to the planes of the gauge-marks.

The open double mortise and tenon joint is made in the same way as the open single, but the thickness of each mortise and tenon is one-fifth the thickness of the sticks instead of one-eighth as in the single open joint.

Regular Mortise and Tenon Joint.—The open mortise and tenon joint (Fig. 338) is a development of the method of halving timbers together. The double open mortise and tenon is a variation of the open mortise and tenon, and the regular single mortise and tenon is a development of the open mortise and tenon. To make the regular style, lay the mortise stick, which we shall call M for short, upon the bench, with the top up. Put the tri-square blade so that its edge shall be directly over one end of the mortise; mark with a knife a point in each edge of the top at the edge of the blade. Then, without changing the blade, rest the tenon stick (which we shall call T), top up, upon M, its flush end flush with the side of M, and one of its lower edges touching the edge of the blade. Mark a point in each edge of the top of M, at the lower edge of T, and over where the other end of

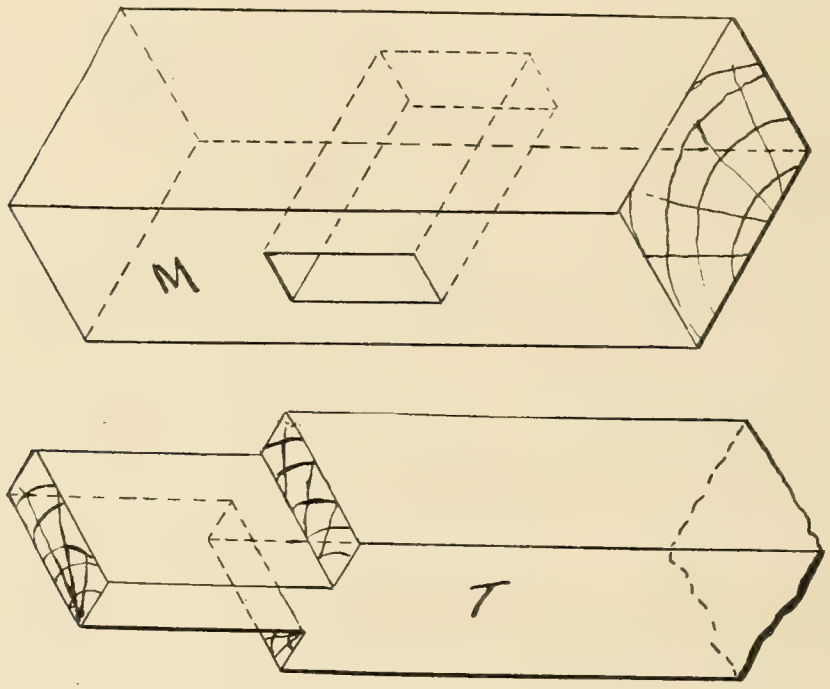


Fig. 338.—Regular Single Mortise and Tenon.

the mortise is to come. Then square down from the four marked points in the top of M and upon the sides of M, making four marks to show where the mortise ends will come. Then mark off upon T the length of the tenon, which will, of course, be determined by the thickness of M, and line all the way around. Then, with the gauge, just as in making an open mortise and tenon, gauge the sides of both mortise and tenon.

To get the wood out of the mortise there are three ways :

1. Bore holes all the way through M, on the central line of the mortise, and nearly to its extreme ends.

2. With a sharp mortising chisel, slightly narrower than the mortise end, cut across the grain one-eighth of an inch from the end of the mortise, the chisel being held straight upright with its straight face next the narrower end of the mortise. This will leave a gap in the wood. Moving the chisel

edge slightly toward the centre of length of the mortise, cut again, and so on until there is at each end a gap large enough to work with, then turn the piece over and do the same thing from the lower side. This will leave the gaps all the way through, and a centre piece of wood remaining.

3. The third way is to take a small bit and bore all the way through the wood, near the end of the mortise; then take a key-hole saw and cut around the four sides of the mortise, rather close to the witness lines, but not touching them.

To remove the rest of the wood, that is, to finish the job, there will be needed two paring chisels, one rather narrower than the sides, and the other rather less in width than the ends of the mortise. The ends should be squared out clear to the knife-marks, the sides being beveled to end in

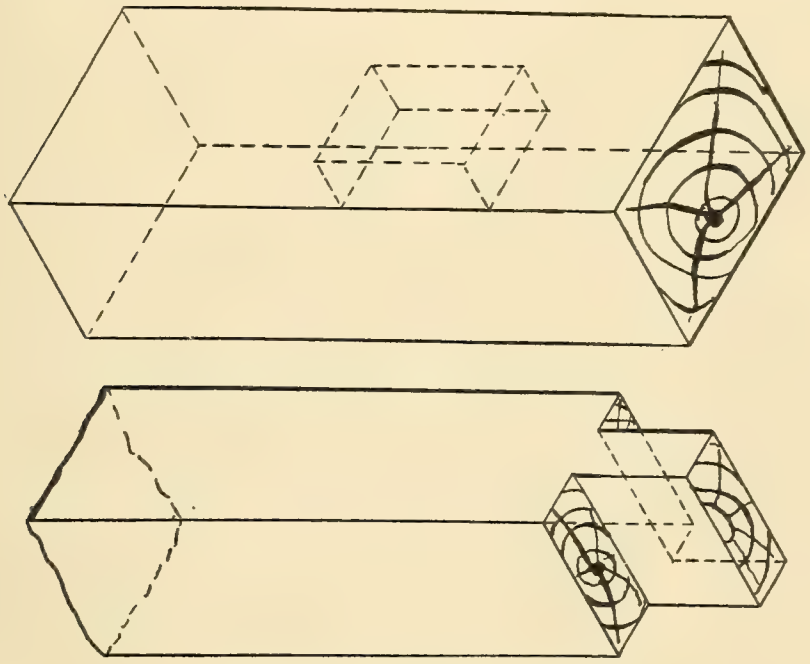


FIG. 339.—BLIND SINGLE MORTISE AND TENON.

straight lines joining the end corners. Then, with a wider chisel, the sides may be beveled to the gauge-marks. Then the ridge may be split away, and the sides pared to the gauge-marks with the wide chisel. One of the straight edges of the chisel may be used to test whether the paring is being done accurately.

Blind Mortise and Tenon Joint.—The blind mortise and tenon is the same as the regular mortise and tenon, except that it does not go entirely through. It is shown in Fig. 339. Sometimes a blind mortise and tenon joint is made at the end of a brace to render it rather more resistant to lateral pressure. It is sufficiently explained in Fig. 340.

Dowel Joints.—The regular dowel joint (Fig. 341) needs less explanation than the half-blind dowel. To make this last we pick out the best piece for the face; lay off upon its inner wide surface, a distance from the end equal to the thickness of the other piece, and line across, then, with

the knife and tri-square, carry this line all the way around. Gauge across the end of the best piece, one-quarter the distance from its flush face, and

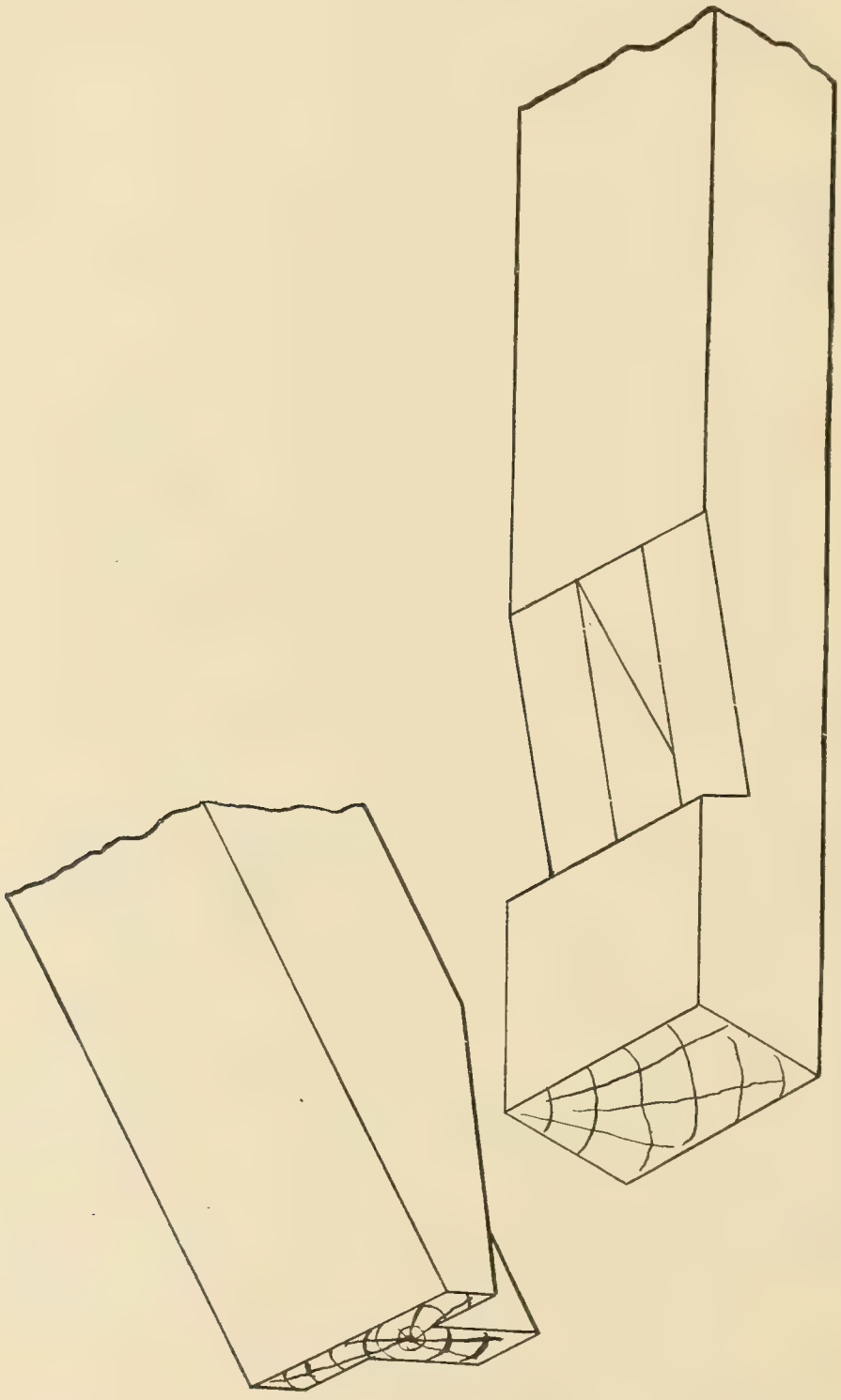


FIG. 340.—OPEN MORTISE AND TENON AT END OF BRACE.

carry this last line along the narrow sides as far as the first line drawn; cut away the part thus marked out; then, holding the end of the other piece in this rabbet (using the vise), bore three or more holes through the end of the

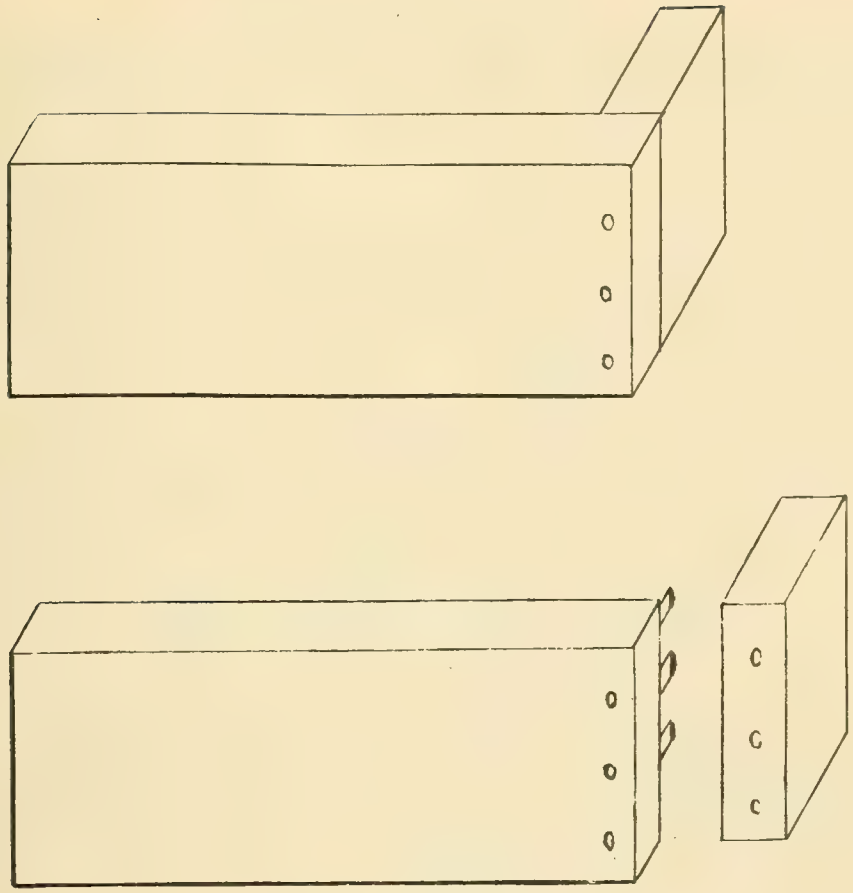


FIG. 341.—REGULAR DOWEL JOINT.

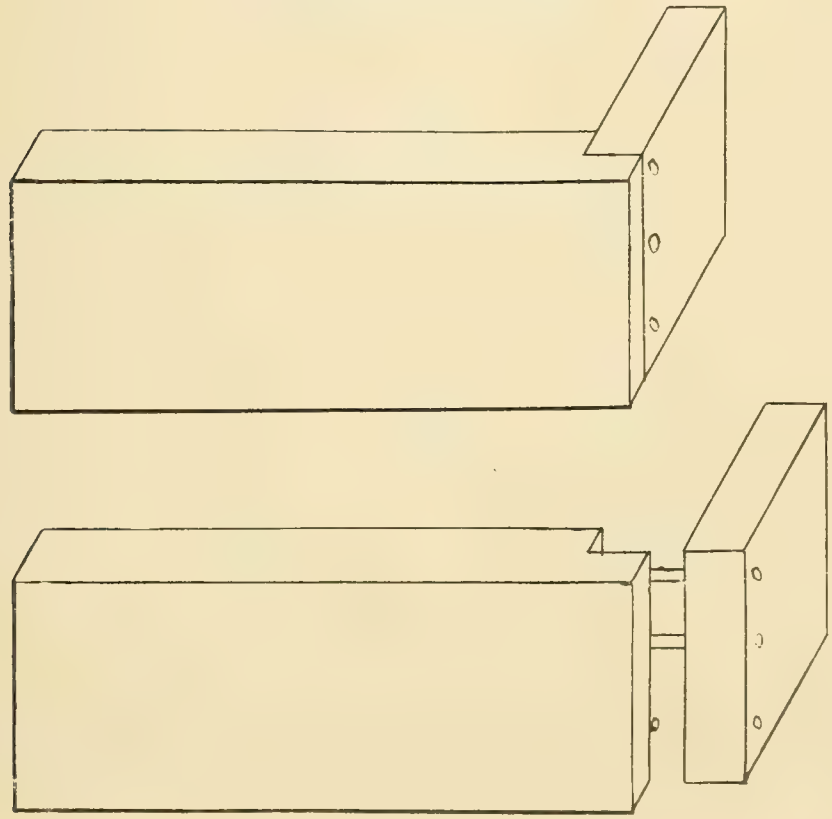


FIG. 342.—BLIND DOWEL JOINT.

piece, running through about an inch into the end of the first, or best piece. These holes we have for the dowels or pins, which should be glued in place with hot glue. The proper size of dowels for a $\frac{7}{8}$-inch board, is $\frac{1}{4}$-inch.

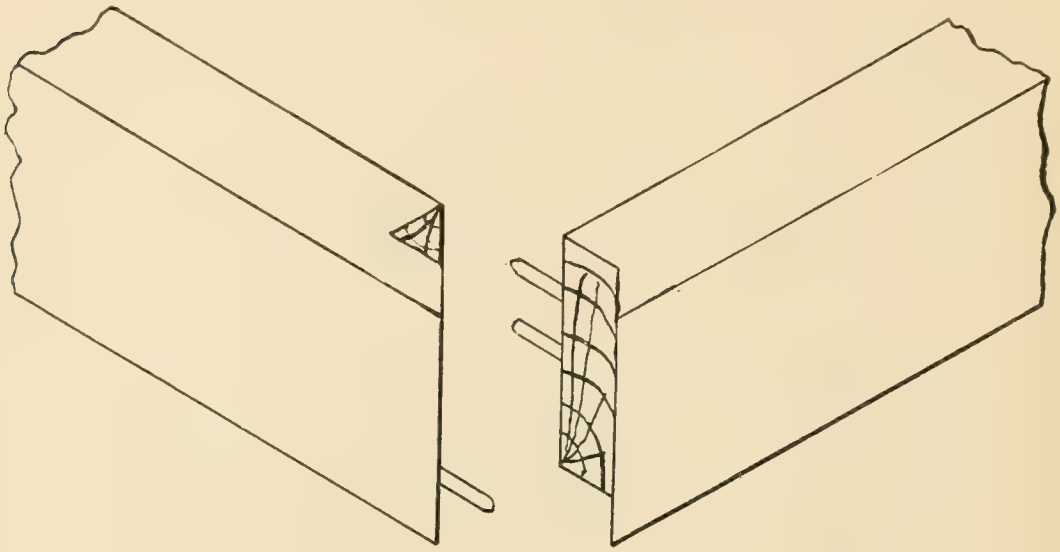


FIG. 343.—BLIND DOWEL JOINT WITH MITRE.

Fig. 342, shows a blind dowel joint, and Fig. 343, shows a blind dowel joint with a mitre.

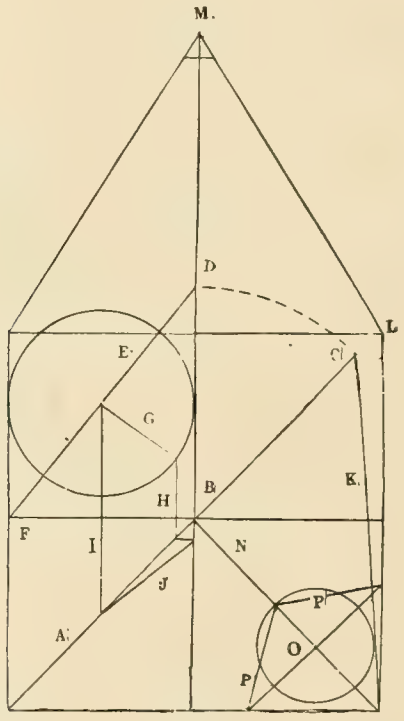


FIG. 344.

Various Methods of Setting the Bevels of a Hopper.*—First strike out the square of the hopper to any scale you wish to work by.

* Adapted from Bookwalter.

Intersect the square both ways in the centre, and strike a diagonal as shown at A; scale off on that line from centre, B, to C, the depth of hopper. Set your dividers at centre, B, and depth of hopper at C, and swing the dividers round until they intersect perpendicular line D. Draw a diagonal line, E, from that point to centre line, F. Set your dividers on line E, so that by striking a circle they will intersect perpendicular line D, and the outside line of square of hopper; strike a right-angled line, G, from centre of line E, until it touches the circle; then drop a perpendicular line, H, down to intersect diagonal line A. Carry that line at right angles until it intersects

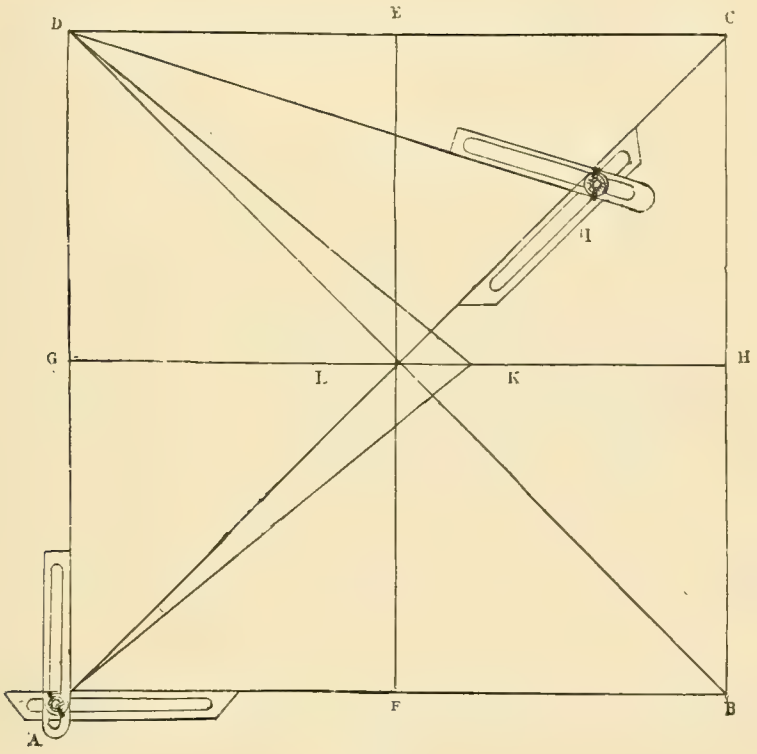


FIG. 345.

perpendicular line D; then drop a perpendicular line, I, down to line A, and draw line J to intersect at line D, as shown. It is by lines I and J that you set your bevel square to cut the corners of the hopper by.

To get the length of sides of corners, strike a line, K, from C to corner of square.

This gives the length of line, L M, intersecting perpendicular line D; and this determines the width of board required, from which to make the hopper. You can make any allowance at point M for hole in hopper that is thought suitable. To get the corner strip to fit the corners, make diagonal line, N, from corner to centre. Set your dividers on line N, wherever you please, and strike a circle that will just touch K. Draw a line, O, through the centre of the circle at exactly right angles to line N, until it intersects the two outside lines of hopper. Draw angular lines, P P, to intersect the circle on line N. This is where the bevel is set, around lines P P, to

get the angle of corner strips. The draft should be carefully and correctly made, and the edges of the boards exactly square where the bevel square is applied to cut the corners. The method here described is applicable for any size, depth or width of hopper required. (Fig. 344.)

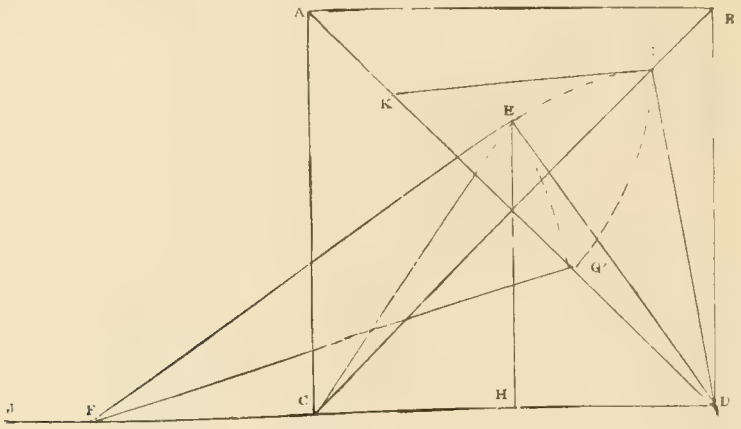


FIG. 346.

Another Method.—Plan the hopper on a large scale. Draw the diagonals A C and D B, also the perpendiculars E F and G H. From the centre, L, lay off one of the diagonals the distance, L I, equal to the vertical depth of the hopper. Connect D I; then the angle, D I A gives the bevel to be applied to the edge of the board to cut the required joint between two ad-

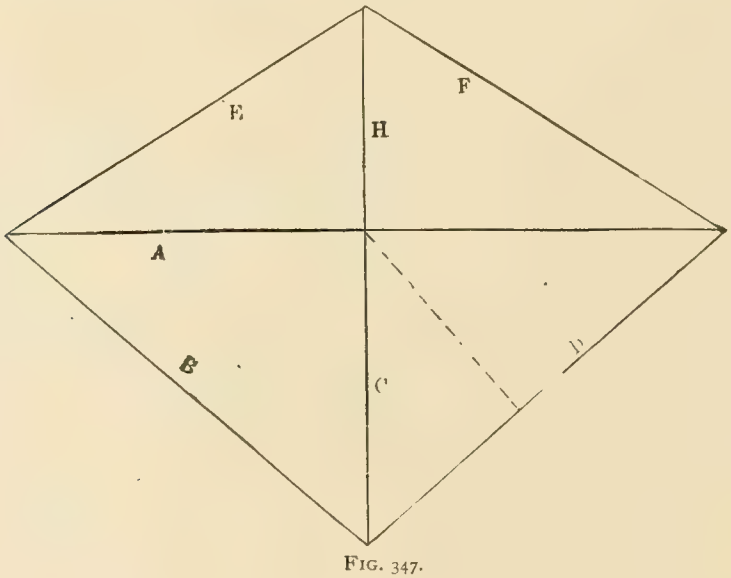


FIG. 347.

jacent sides. Next make D K equal D I and draw D K and A K. Then will the angle A D K or K A D give the required bevel to be applied on the surface of the board in order to cut the sides of the proper slope, and give them the proper inclination. (Fig. 345.)

A Third Method.—Ascertain the size you want your hopper on the top, then make a draft according to the size, as A, B, C, D. Then find the depth

you would have the sides, as H E. Draw one side piece, C E D. Extend the line C D any distance, as to J. Then draw a line from the point E, perpendicular to the line D E, until it intersects C D, say at F. Then set the dividers with one point at E and the other at F, and sweep E G until it strikes the line A D. Now draw the line G F. The angle A G F would be the angle required to set the bevel for the mitre of a hopper of any size. Then place the bevel to correspond with the lines A G F. To prove it with the dividers or tram, take the distance D E, and sweep to I, on a line from B to C. From the point I raise a perpendicular, I K, to the line A D. Take the distance K I and sweep to G; and if the circle I G and the line F G meet exactly at the point G, the work is right. (Fig. 346.)

A Fourth Method.—Let the lines, A, B, C, D, in the diagram represent a hopper three feet square on top and twenty-two inches deep, standing cor-

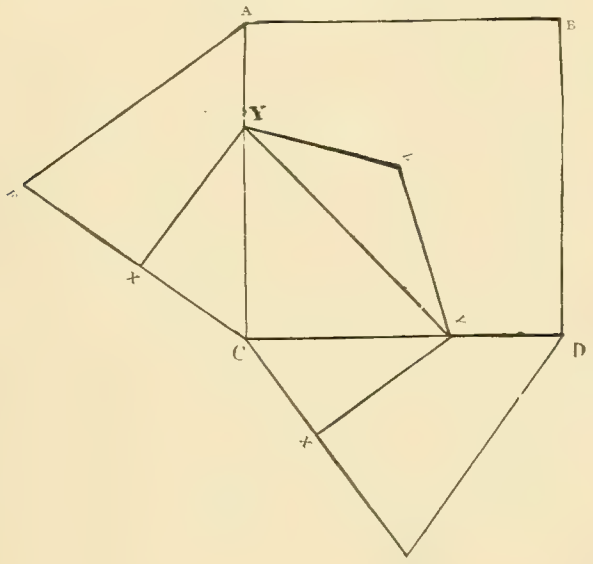


FIG. 348.

nerwise to the reader, and measuring a trifle less than fifty-one inches across the top. Now measure distance from centre of hopper to one of the corners at right angles with such corner (as shown by dotted line) and lengthen the upright line C just so much, as at H; from which point strike lines E and F to the corners of the hopper. Set your bevel by these lines for corner pieces, and also for joints of hopper, if square joints, or by one of these lines and the upright line H, for mitre joints. (Fig. 347.)

A Fifth Method.—Let the square, A B D C, represent the top of the hopper; C D E and C A F the two adjoining sides, of any desired depth. Select the points X X at pleasure, equidistant from C, and draw the perpendicular X Y. Draw the diagonal Y Y, upon which erect the isosceles triangle Y Y Z, making the sides Y Z equal to X Y, the angle Y Z Y being the angle or bevel sought. To demonstrate: Cut the outline of the diagram from a piece of pasteboard; draw the point of a sharp knife along

the lines A C and C D ; now fold the two adjoining sides so that the lines C F and C E shall join. It will now be seen that the angles Y Y Z and Y Y X are equal, Y Y X being the proper angle delineated upon the side of the hopper. (Fig. 348.)

Building an Overshot Wheel.—We will suppose that there is to be constructed one of the old-fashioned overshot water-wheels, all of wood, say twenty-two feet in diameter and fourteen feet face, for a fall of twenty-four feet. This is to be a plain wheel with straight buckets, and built in two divisions. The material employed should be white oak, as long seasoned as possible, and by natural means, not in a kiln. The shaft must be two feet in diameter, sixteen-sided, and, of course, must be dressed from a log more than twenty-four inches in diameter at the smallest end. This wheel will have arms and segments also of oak ; there will be iron gudgeons or journals fastened to the shaft in any one of several manners, we will say by a cap fitting over the end of the shaft ; this cap, which will be cast in the same piece with the gudgeon pin or journal, will be three feet four inches in diameter, and pinned on by square pins. The journals should be as long as possible ; we will make them six inches in diameter and at least twelve inches long. (Most journals are too short. It must be borne in mind that diameter of bearings, while it increases the strength, also causes greater loss of power by friction, by reason of the greater leverage that the resistance has to overcome. To diminish friction—that is to diminish the loss of power by friction—bearings should be as long as possible.) These journals will run in cast-iron boxes truly bored out or run with babbitt-metal. For the foundation and support of the wheel there should be a stone wall, upon the top of which are bolted heavy timbers. All the timbers should be air-seasoned, if possible, and the ends should have been painted, to prevent checking or splitting. The log should be felled about the time the sap is running out. The small end may be about two feet eight inches in diameter, the large end coming, of course, whatever it will be—perhaps three feet one inch for a length of twenty-five feet.

First this round log must be squared up. There must be described upon the small end (first squared off) a circle twenty-four inches in diameter, and the circumference of this divided into sixteen equal portions by a compass. There must be inscribed in it a square, an octagon, and a sixteen-sided figure, which will represent the end of the finished shaft and the diagonals of these drawn ; then the large end must be marked out in the same manner. To do this there must be made two "try-sticks" about three feet long, half an inch thick and two inches wide, perfectly true. To get these perfectly true there must really be made three, each of which must be tried with each of the other two. By means of these two try-sticks the squares at the two ends of the log may be made exactly true with one another, that is, so that each angle of one square will exactly cover the angle of the other, and that the line drawn from one angle at one end to the corresponding angle at the other shall not have any pitch or "wind," but that the plane containing them shall be perfectly parallel with the line connecting the two centres of circles on the ends of the log. This being settled definitely, the log may be

roughed out with the common axe, and then more nearly to the outline of the sixteen-square with the broad axe, being sure not to cut too close to the line, but to leave enough space for finishing, and to guard against mistakes. Then, picking out the straightest side, dress off a spot at one end, parallel with and forming part of one of the sides of the sixteen-sided figure ; then one at the other end of the log, and with the two try-sticks make these perfectly true with each other, that is, out of wind, so that the line of sight from the two try-sticks placed across these two spots shall perfectly coincide all along their length. If these two try spots be perfectly true with each other and with the axis of the shaft, there need be little trouble in dressing the other sides so as to have them exact. Then the chalk line will be used to lay out the lines representing the edges of the faces of the shaft, the stick being turned over until all the lines are scribed. It is better to use a straight-edge the length of the stick, because with this and the scriber the line can be made finer and truer than with the chalk line and chalk or with pencil. Having roughed out the sixteen-sided stick true, but not to dimensions or perfect in surface, the jack and fore planes may be used to finish.

The cast-iron caps of the gudgeon should be, say, fifteen inches long, and if cast with a round socket the ends of the shaft should be dressed with adze and 3-inch chisel to correspond; but it is best to have it cast "sixteen square." The chisel employed will be the millwright's chisel, which is very heavy and having a very heavy handle. In every other side of the shaft there must be holes for the bolts or the wood screws which hold the cap to the shaft end. If wood screws are used, they should be ten to twelve inches long, and they should be set "staggering," that is, those in one face at one end of the cap, those in the next face at the other. The holes for these screws must be made with a $1\frac{3}{8}$-inch auger, so as to give one-eighth of an inch draft. This water-wheel will have eight arms at each end, set staggering, that is, the arms in one end being in the even sides, those in the other in the odd sides. For this size wheel the arms should be 4×6 inches in cross section at the big end or that next the hub, and tapering one and a half inches in ten feet. There should be cast in the gudgeon sockets for these arms, or mortises to let them pass through into the shaft mortises.

In framing a mortise 3×5 inches for the arms (which must have a shoulder), take an inch auger and bore the depth of the mortise across the ends, being very careful not to touch the outlines. Of course the face must be dressed up first so that it shall be perfectly true, as on this face must largely depend the plumbness or truth of the mortise, and, of course, of the arm that it contains. The space between the auger holes must be dressed out with a $1\frac{1}{2}$-inch framing chisel. By rights there should be used a corner chisel, each face of which is one inch across. (This corner chisel has two faces at right angles, and by it it is impossible to make a mortise with any acute angles, and almost impossible to make any obtuse angles.) To be sure that the mortise is perfectly plumb or true, that its sides are parallel to the radius through its centre, the square must be used. To effect this, use the square on the sight stick, to get the face at right angles to the radius, and then use the small square in the mortise. A 4×6 arm might have a half-inch

shoulder on each side. The arm should be dressed perfectly true before the mortise is dressed out. There is no tenon on the other end of the arm, as the rim segments are bolted on. The segments of the rim should be of the same material as the shaft and arms; they should be four inches thick by twelve inches face, although, perhaps, ten inches would be wide enough. If the wheel were twenty-two feet in diameter it would have a circumference of about sixty-nine feet, and there would be about thirteen segments. These should have a scarf fifteen inches long at each end, the stuff being "halved" together and bolted with three $\frac{1}{2}$-inch bolts. The arms should be bolted to the inside of the segments with $\frac{1}{2}$-inch bolts. In the centre the arms should be a little to one side of the exact centre of the shaft length, in order that they might be bolted to the sides of the segments, which should be in the centre of the length of the rim. The sheeting should be of $1\frac{1}{2}$-inch plank, fastened on with $\frac{5}{8}$-inch bolts.

To frame the rim together after the parts have been worked out, there should be made a platform—made by taking a large block out from the end of a round log, and about two feet in length, planting it on a level place, and running out a spider of eight or ten pieces of common 4×4 stuff, these arms reaching as far as the circumference of the wheel would come. Each outer end of the arms of the spider should be supported by an upright piece of stout common stuff; and this platform or spider must be perfectly true or plane; not necessarily level, but certainly plane. When I said that the end of the segments of the rim should be "halved" together, I should have added that this is simply a technical expression, for the scarf on the side that is to receive the grooves of the buckets must be the thickest, to allow for the weakening by cutting. The rim can be laid up true by the use of a sweep centred in the centre of the platform. By means of pins placed in holes bored in the spider the segments can be all framed exactly true and alike. After the frame is dressed true the buckets and "elbows" can be laid out. The elbows, running radially, are of 2-inch stuff, and, say, four inches wide, placed one foot apart.* The elbow grooves may be about three-quarters of an inch deep, and as wide and long as the elbows are thick and wide; then the bucket grooves may be cut out, being laid off on such an angle as to let the water run out just before the bucket gets to the lowest point in its revolution. The bucket grooves are somewhat narrower at the inner end than at the outer, and there should be a strip of just the right taper to allow this, say one-sixteenth of an inch in a foot. By the use of this strip the buckets may be dressed off at the proper size and taper to fit the grooves. The other end of the rim will, of course, have the grooves on the other side, or, what is the same thing, running left-handed to those in the first rim. The middle arm may be thicker than the end-pieces and be grooved on both sides. After the arms are fastened in the shaft, a circle should be swept upon them, of the size of the inside of the rim; then the rim may be bolted on; or the outer ends of the arms may have a shoulder cut down to this circle. Of course, before the mortises are laid out in the shaft it must be decided

* See Chapter on Water-Wheels.

which way the arms are to be fastened to the rim, so as to allow the proper distances between the mortises, etc. After the elbows are in place, the soling is put on, this being of edge-beveled strips. Each bucket should be cut to length as it is put in, as the rims will warp some. Another way to fasten the buckets on is to have the whole wheel covered with a soling, and to bolt to the outer edge of the rims triangular pieces two and a half inches thick, and of the angle the buckets are to set at; the buckets to be bolted to these angle pieces by two $\frac{5}{8}$-inch bolts at each end and two in the middle. The buckets should be one and a half inches thick, beveled on the edge next the sheathing and square on the outer edge. There are inside segments of four inches square, or 4×5, to stiffen the sheathing, half way between the ends and the centre segments. To one of the end rims there may be bolted a cast-iron segmental spur-wheel rim varying in thickness according to the power to be transmitted.

CHAPTER XXXIX.

COMPOSITION AND STRUCTURE OF THE WHEAT BERRY.

[For the preparation of the following very interesting treatise the author is indebted to his assistant, Mr. Victor S. Delacroix.]

A knowledge of the physical formation and chemical composition of cereals is the basis of construction of all milling machinery. Knowing that which is chemically most valuable, and its position in the grain, we are better able to construct machinery which will save and properly treat it, and, at the same time, separate and eject all such parts as injure the character and value of the desired product.

In order that our knowledge of cereals may be intimate and complete, it is necessary to study them in two ways, chemically and physically.

By the first method we are able to place a valuation on special elements and parts of the grain structure, while by the second may be located these more valuable constituents of the cereal.

Thus, while chemically we may discover which bodies are chemically most valuable, it is of the greatest necessity that these valuable parts be localized, and hence the necessity of physical study of the grain structure.

A chemical analysis of wheat shows the following bodies to exist in that grain, and detailed analyses of these bodies show them to be composed as follows :

According to Boussingault, the analysis of wheat examined by him was as follows :

Water,	14.83
Gluten,	19.64
Albumen,	.95
Starch,	45.99
Gum,	1.52
Sugar,	1.50
Oil,	.87
Vegetable Fibre,	12.34

The following-named elements enter into the composition of above specified bodies in these proportions :

	Gluten. Per Cent.	Albumen. Per Cent.	Starch. Per Cent.	Gum. Per Cent.	Sugar. Per Cent.	Vegetable Fibre. Per Cent.
Carbon,	53.27	53.74	42.80	42.68	36.1	53.23
Hydrogen,	7.17	7.11	6.35	6.38	7.0	7.01
Nitrogen,	15.94	15.66	....	....	....	....
Oxygen,	....	....	50.85	50.94	56.9	16.41
Sulphur,	23.62	23.50	....	....	....	23.35
Phosphorus,	....	....	....	....	....	....

These constituents named in analysis No. 1 may be classified according to their chemical composition into two classes, nitrogenous and non-nitrogenous bodies.

The nitrogenous bodies are gluten, albumen and cerealine (not mentioned in the analyses), while the starch, vegetable fibre or cellulose oil, gum and sugar represent the non-nitrogenous, or, more properly speaking, the carbo-hydrates. All of these are valuable as food, except cellulose, which, from its indigestibility, has little value as a food. It would be well, perhaps, to casually glance at the chemistry of the nitrogenous elements of the wheat berry.

Wheat, from the large percentage of gluten it contains, is the most valuable of all the cereals, and it may be truthfully said that the amount and character of the gluten fix the value of the flour under consideration.

According to Rittenhausen, gluten is composed of four nitrogenous bodies their chemical composition being given in the analysis:

	Mucedin.	Fibrin.	Gliadin.	Casein.
Carbon, . . .	54.11	54.31	52.67	52.94
Hydrogen, . .	6.90	7.18	7.10	7.04
Nitrogen, . . .	16.63	16.89	18.01	17.14
Sulphur, . . .	0 88	1.01	0.85	0.96
Oxygen, . . .	21.48	20.61	21.37	21.92

Gliadin, or vegetable glue, is soluble in water, while fibrin, casein and mucedin are not.

It is to mucedin that the characteristic toughness and elasticity of gluten is due.

Fibrin and casein are products readily derived from gluten by treatment with alcohol.

Gluten is easily obtainable by washing flour in a stream of water. If, say, an ounce of flour is inclosed in a piece of Swiss muslin or very fine bolting cloth, and a stream of water is allowed to run upon it, the mass being squeezed while washing, there will be left a grayish mass, of a sticky tenacious character, and which is at first tough and elastic, but becomes brittle when dry, and putrifies, under favorable circumstances, like animal tissues.

If gluten is boiled with alcohol, there will be obtained, first, a grayish residue fibrin, and, second, on cooling, a percipitate, which is casein. Fibrin represents about 65 or 70 per cent. of gluten.

The alcohol may now be boiled to a syrup, and then diluted with water, and the gluten (containing probably a little fatty matter) may be recovered. The fatty matter may be dissolved out by ether.

There exists in wheat, besides these, two other protein bodies, albumen and cerealine.* The former occurring intermixed with the starch and the various juices of the cereal, while, as far as is known, cerealine is located and identified with the bran, and is supposed to be a diastasic ferment.

* Discovered by Mège Mouriès.

Of the carbo-hydrates (non-nitrogenous elements), starch is the most abundant, forming about 45 per cent. of the berry. It is intended as food for the germ. There are embodied in every starchy grain certain elements necessary to transfer this starch into other products more easily digested; these are called diastases, of which maltose and pepsin are familiar examples. Most of the starch in the wheat berry is formed in the centre of the grain, inclosed in cells of hexagonal shape, with walls of cellulose. The percentages of starch, as found in the more prominent cereals, is given below:

Wheat,	49.99
Rye,	60.91
Corn,	62.05
Buckwheat,	65.05
Oats,	63.00
Rice,	89.1

Starch (amidon) is identical in composition with cellulose, and supposed by some to be a development of vegetable mucus.* It occurs in several forms, and of differently shaped and sized granules, usually containing a nucleus or hileum. True starch may always be detected by iodine, giving a characteristic blue color with that substance. By decomposition, or more properly, transposition, it may be changed into glucose or dextrine, etc. It is on this principle that the glucose industries are being built up.

The rotary power of starch is 211°, while dextrine is 176°.† By boiling starch with some acids, such as oxalic acid, it may be transposed into dextrine and sugar; but although this transposition may be easily effected, to change inverted starch (glucose) or dextrine back to starch proper has never yet been accomplished.

Starch is insoluble in water, usually, white and glistening in appearance, and under the microscope exhibits a characteristic formation and shape varying according to the special source from which it was derived. According to Payen and others it is formed only when nutriment is in excess, and is dissolved and used up in a later stage of the cereals; and although not nutritious as starch, it becomes eminently so when transposed into dextrine, glucose, etc., and combined with nitrogenous elements found in all cereals.

The other carbo-hydrates are dextrine, gum and sugar. As these are properly products of transposition, it is doubtful if they exist at all in certain stages of the cereal's growth. They are more abundant in flour than in wheat, being produced by the process of granulation. Dextrine is represented by the brown crust on bread.

The oil in wheat is localized in greatest quantity in the germ,‡ which is chemically composed of the following elements:

Starch,	41.22
Albuminoids,	22.66
Gum and Sugar,	9.72
Fat and Oil,	5.40
Cellulose,	5.96
Ash,	3.99
Water,	11.05

* Schleider. † Béchamp.

‡ It may be readily seen how valuable the germ, from the large percentage of nitrogenous matter it contains, would be as a food; but the discoloration of the flour by the oil renders it hurtful as a constituent of flour.

Now, there remains but to glance at the bran. Having looked at the inside, we will examine the covering.

Professor Cameron gives the following analyses of the brans of three kinds of wheat: Black Sea wheat (from Russia), California and American spring wheat: *

Constituents.	Bran from Black Sea Wheat.	Bran from California Wheat.	Bran from American Spring Wheat.
Water,	14.35	13.05	14.77
Albuminoids,	14.13	2.36	16.29
Oil,	3.77	4.65	4.30
Starch, etc.,	51.65	55.21	47.98
Woody Fibre,	10.50	11.43	10.66
Mineral Matters,	5.60	6.30	6.00

WHEAT RAISED IN GERMANY: CHEMIST UNKNOWN.

Starch,	47.98
Albuminoids,	16.29
Water,	14.77
Cellulose,	10.66
Oil,	4.30
Mineral Ash,	6.00

According to Horsford, the mineral ash of wheat is composed as follows:

Potash,	30.00
Soda,	3.50
Lime,	3.50
Magnesia,	11.00
Oxide of Iron,	1.00
Sulphuric Acid,	.50
Silica,	3.50
Chloride of Sodium,	.50
Phosphoric Acid,	46.50

In neither of these analyses is mention made of cerealine, as the presence of this body has not been discovered until quite recently. On comparing these with other analyses, discrepancies will no doubt be discovered; but these are due to the analyses being either for different varieties of grain or

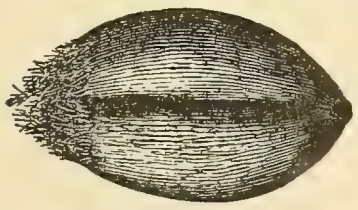


FIG. 349.—WHEAT, NATURAL CONDITION, HIGHLY MAGNIFIED.

FIG. 350.—SHOWING GRAIN AFTER HAVING PASSED THROUGH A BRUSH MACHINE.

from the special method of analysis used by the chemist. They have been selected as made by standard authorities, and we believe that they are approximately correct.

We now come to the physical examination of the wheat structure.

* *American Miller.*

Fig. 349 represents a grain of wheat in its natural state, while Fig. 350 shows a portion of the same after having passed through a smutter, and as it appears without its silicious coat. It will be noticed that on the end of the berry (Fig. 349) there is a fuzz or "beard," made up of hair-like bodies, of cellulose.

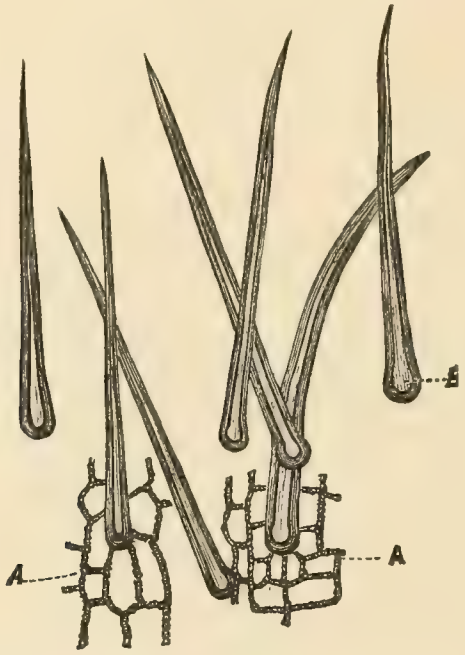


Fig. 351.—Hairs or Beard of Wheat Berry Highly Magnified.

Fig. 351 shows the hairs at the end of the berry, greatly magnified. These hairs are composed of a single cell, with very thin cell-walls inserted in the outer covering of the wheat, penetrating the cellular tissue, as shown by the figure.

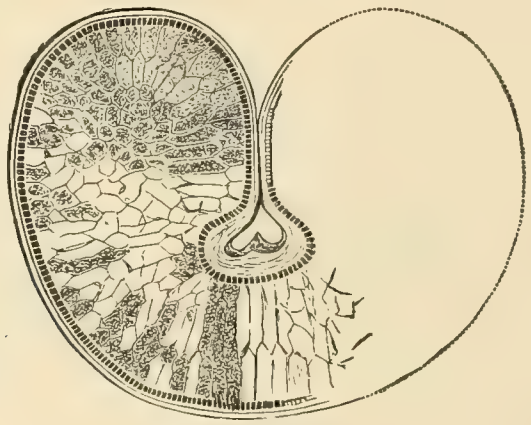


Fig. 352.—Cross Section of Wheat.

The envelopes inclosing the starchy centre of the wheat berry may be roughly computed as consisting of six coats. These are formulated in "Cerealia" * as follows :

* A very interesting and quite complete little pamphlet by Mr. Jno. D. Nolan. We would here acknowledge the use of some cuts from the same work.

FRUIT COATS.

1. The epicarp, or outer coat of longitudinal cells.
2. The mesocarp, or inner coat of longitudinal cells.
3. The endocarp, or coat of transverse cells—the cigar coat.

SEED COATS.

4. Episperm testa, or outer seed coat.
5. Tegumen, inner seed coat, or gluten comb coat.
6. Layer of gluten sacs.

Fig. 352 represents a cross section of wheat, magnified 225 times. The inner ring of irregular black dots is supposed to represent the gluten. The inner portion is made up of starch, inclosed in hexagonal cells. It also shows the crease, which gives the miller so much trouble from retaining dirt and foreign matter, which discolors the flour.

Fig. 353, on following page, represents a longitudinal section of a grain of wheat made by Mège Mouriès, and the various tissues are numbered as follows :

1. Outer or first coat.
2. Epicarp, or outer coat of longitudinal cells.
3. Mesocar longitudinal cells, but with the greatest length of cell running perpendicular to those of the outer coat.
4. Endocarp, or inner fruit coat of transverse cells.
5. Episperm, testa, or outer seed coat.
6. Embryo membrane, or expansion of germ.
7, 8 and 9. Gluten cells containing starch.
10. The germ.

The first three coats are fruit coats, consisting of woody fibre, similar in composition to straw. They are easily separated from the wheat.* But we will consider their construction more in detail farther on.

Nos. 4, 5, 6 are the membranes causing so much trouble in flouring.

The external testa, or episperm No. 5, contains the coloring matter, usually light yellow and orange yellow. The intensity and predominance of one of these colors gives the wheat its name, white, amber, reddish or red, as the case may be. It represents less than 2 per cent. of the berry.

No. 6 is that portion of the berry which produces the best flour, being harder and richer in gluten. This, mixed with equal parts from the centre, produces the finest white flour.

No. 7 is still richer in gluten.

Nos. 8 and 9 mixed together form a high grade flour of good color, and one hundred parts of this flour would produce one hundred and thirty-seven parts of bread.

Fig. 354 is the first coat or epicarp, very highly magnified. It is composed of irregular longitudinal cells with the thick walls, very common to epithelial structures. The greatest length of the cells corresponds with the longitudinal section of the grain.

Fig. 355 represents a section of the inner fruit coat, endocarp, or coat of transverse cells, sometimes called the cigar coat. These cells run with their

* These tissues represent about 3 per cent. of the berry.

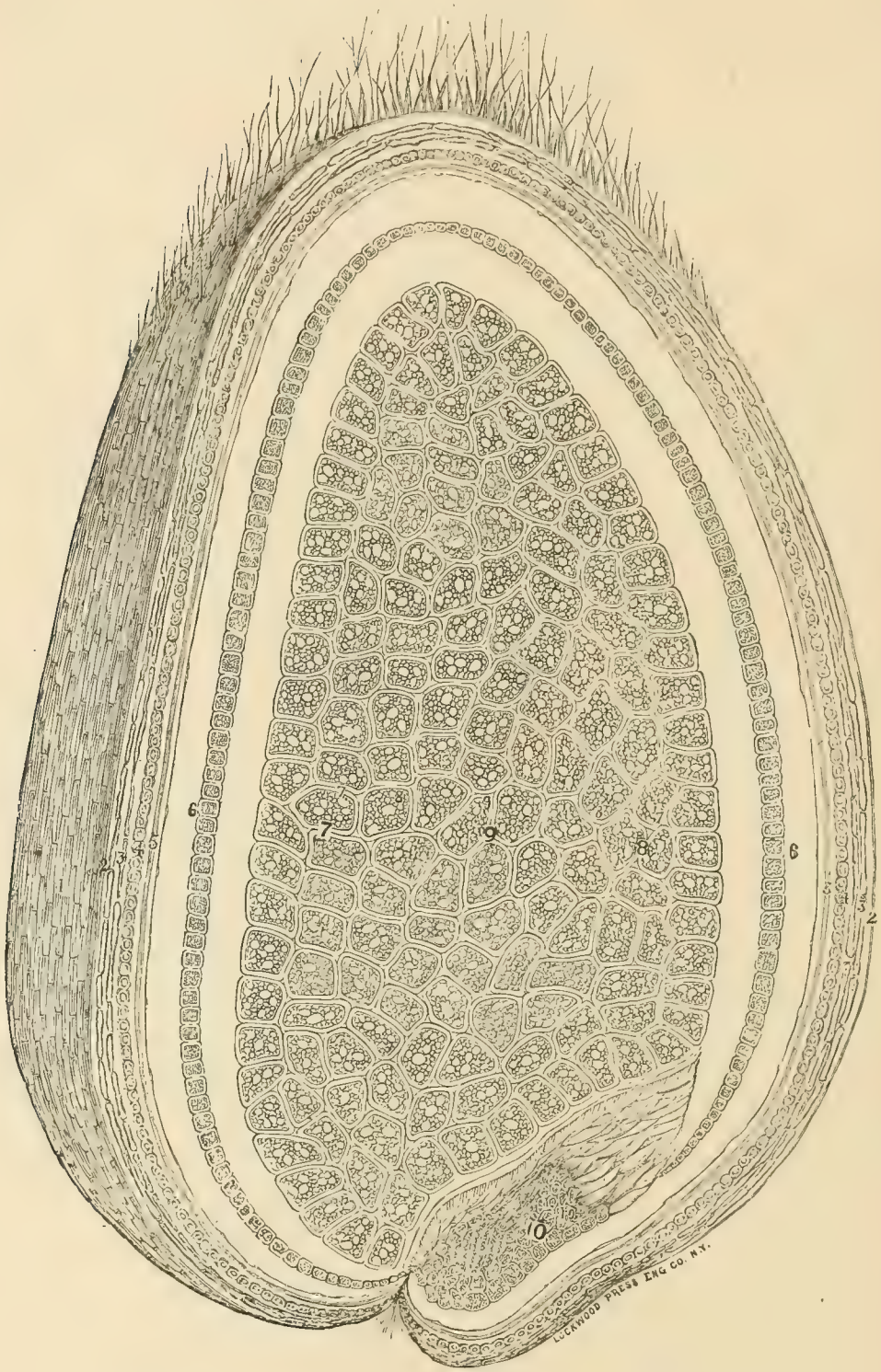


FIG. 353.—LONGITUDINAL SECTION OF WHEAT, WITH IMAGINARY WHITE SPACES, TO RENDER TISSUES MORE PROMINENT.

greatest length perpendicular to the outer coat or with the smallest section of the berry.

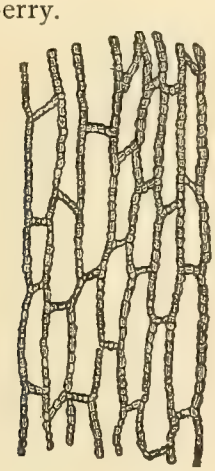


FIG. 354.—EPICARP.

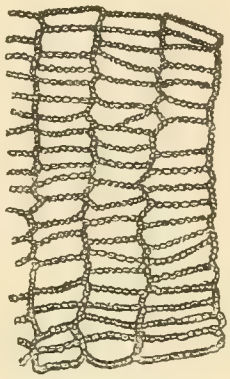


FIG. 355.—ENDOCARP.

The cellular structure of the central portion of the wheat berry is very nicely shown by Fig. 356.

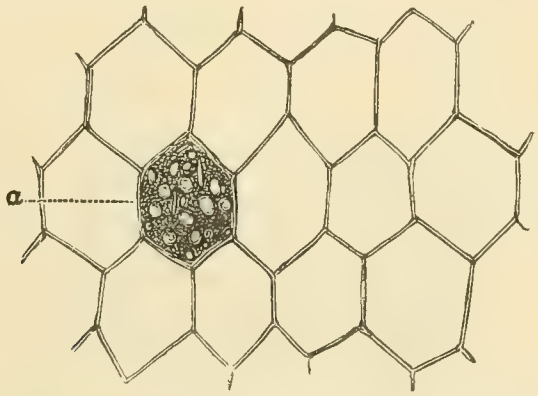


FIG. 356.—CELLS FROM CENTRES OF WHEAT GRAIN. *a* FILLED WITH STARCH.

The cell walls are composed of laminated cellular tissue of extreme delicacy. The central portion, No. 9, contains the cells most heavily loaded

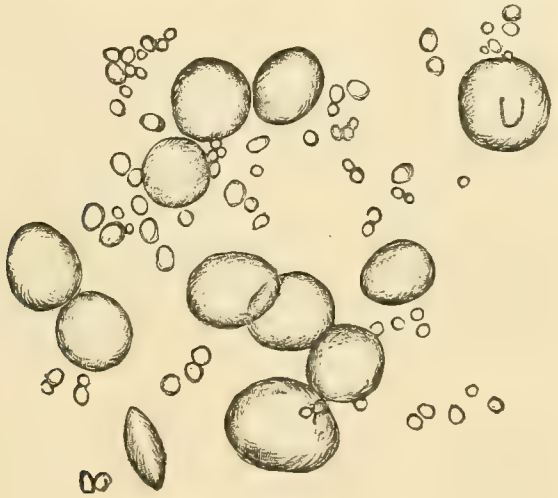


FIG. 357.—DIEHL WHEAT STARCH.

with starch, and yielding a beautifully white flour of little consistency, and incapable of making light digestible bread.

Fig. 357 represents starch from Diehl wheat. The smaller grains are principally composed of broken portions of gluten and other nitrogenous matter.

Fig. 358 is starch grain of Clawson wheat, highly magnified. This is

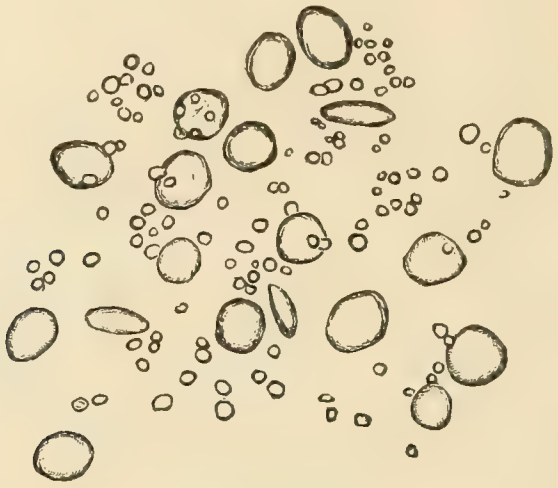


Fig. 358.—Clawson Wheat Starch.

the richest in starch of any wheat grown. It yields plentiful crops, and gives a beautifully white floor of little body.

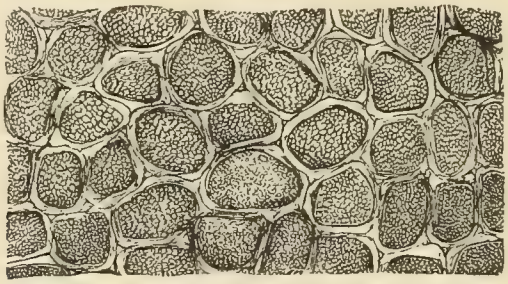


Fig. 359.—Outer Layer of Nitrogenous Elements.

Fig. 359 corresponds in section to seven of the larger cut. It is that portion of the berry containing the greatest amount of gluten. Being imme-

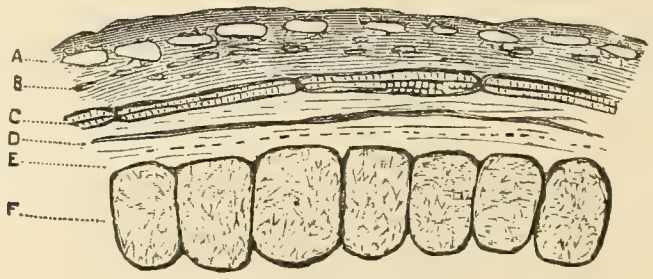


Fig. 360.

diately next the tegumen, or inner seed coat, and as its separation from this coat is difficult, it produces a dark flour very rich in gluten.

Fig. 360 is another part section of wheat, showing the fruit and seed coats and gluten grains more highly magnified.

The art of milling is to manipulate the grain so as to obtain the greatest percentage of most valuable material.

A glance at the chemical composition of bran will show at once its unfitness as a food, consisting of from 10 to 12 per cent. of woody fibre, which is totally indigestible. It should, therefore, be rejected as useless as a nutritive product of flour, being not only worthless as a food, but injuring the market value of product by discoloration. The germ, though very nutritious in character, has to be rejected also for the latter cause, as well as by reason of the oil it contains causing rancidity from oxidation.

The "strongest" flour is a dark flour, and hence less valuable from a money point of view.

Wheat of the same variety from which section Fig. 353 was made, yielded these results when floured:

		Gluten and	Produces Bread.
100 parts of flour in centre	contain	8 "	128 parts.
" " first layer	"	9.2 "	136 "
" " second layer	"	11 "	140 "
" " external layer	"	13 "	145 "

The flour from the external layer is so dark as to make a brownish bread, and is, hence, less sought for and less valuable commercially. It would seem that the lines of advancement in milling would be those of granulation, bran cleaning and wheat meal purification before bolting, especially the latter, and by methods depending on other qualities than size, as in grinding the bran is reduced as fine as the flour, and separation by size is therefore an impossibility.

Many valuable improvements in milling machinery have been made during the past few years, and it is to be hoped that the next decade will see a corresponding advancement.

CHAPTER XL.

GRAIN DESTROYERS.

Vegetable Organisms—Weevils—Rats.

All kinds of grain are preyed upon by living organisms of animal or vegetable origin. From the time it is sown in the ground to its storing in the granary it is the accepted food of myriads of hungry organisms, some attacking it in one stage of its growth and some in another. For convenience, the parasites which ravage our crops may be divided into two classes, vegetable and animal, and a casual glance at the most prominent and rapacious will probably not be amiss.

Vegetable Organisms.—Of those of vegetable origin, the following are the most common in the work of destruction: Smut, rust and brand, mildew and ergot. These vegetable organisms are parasitic fungi which live upon the juices of the plant and work destruction either directly in the grain itself, as wheat smut, or destroy the vitality of the plant, as rust, brands, etc. These plants multiply and reproduce themselves not by means of pollen, as is the case with many plants, but by spores, the fructification of which produces sad havoc. Smuts are parasitic fungi, the filaments of which grow through the cell walls of the plant, absorbing its juices and tissues. The ends of these filaments become articulated into cells developing into spores. These spores form the brownish black powder observed on the wheat and oats.

The sporules of wheat smut or bunt (*Tilletia caries*) fructify within the berry itself. On pressing a grain of wheat affected by smut, it bursts with slight pressure, and is found to be filled with a blackish powder emitting a nauseous odor of trimethylamine, a volatile oil which is also found in herrings. There are several other varieties of this parasite, as oat smut (*Ustilago carbo*), which affects the panicle or raceme of oats; and corn (maize) smut (*Ustilago maydis*), affecting the female corn cob.

Rust and brands are parasites which, instead of working destruction directly in the grain itself, destroy the leaves, infecting them with reddish pustules or cup-like protuberances. If a field of infected grain be examined, on the under side of the leaves will be noticed these reddish pustules or cups, which developing, the germ tubes force their way through the epidermis and branch out filaments on the inside of the leaves which articulate into cells producing sporules. These cluster cups are often found on other plants, and the spores from them on coming in contact with the cereals will at once commence to germinate. The cluster cups of the barberry produce spores which cause a very dangerous form of rust (*Uredo linearis*), while the

well-known rust (*Uredo rubigo*) of the cereals has its origin in cluster cups growing on other plants in the neighboring fields. That the diseases of wheat known as rust and brands were produced by sporules from parasites growing on other plants in the neighborhood of the fields has been proved beyond the shadow of a doubt by Professor De Bary, of Strasburg. Mildew (*Eurisiple graminis*) is a parasitic fungus feeding on the juices of the plant and impairing its growth. The appearance is that of a white fuzz. Other varieties of mildew are very destructive to fruit trees.

One of the most peculiar and dangerous diseases to which cereals are exposed is the ergot. Tulsane was the first to show the immediate connection which existed between the different stages of development of this peculiar disease. The mucous, honey-like substance called honey dew by the farmers is the second stage of development. If this honey dew is highly magnified it will be found to be swarming with sporules. These spores are found to issue from a slender mycelium or filament which afterward hardens and becomes the ergot grain. This develops the next spring into the third condition, or *Claviceps purpurea*, which causes fatal poisoning. The German name of the ergot is *mutterkorn*, from its causing contraction of the uterus. In 1771, whole villages in Westphalia and Hanover were poisoned, and in certain villages over 90 per cent. of the cases proved fatal. Ergot is now largely used in obstetrics, and is known in this connection as *Secole cornutum*.

Weevils.—The weevils which give the most trouble are probably the grain weevil, *Calandra granaria*, and the rice or black weevil, *Calandra oryzæ*.

The grain weevil is a reddish little beetle, with a long nose or snout, surmounted with two club-like *antennæ*, or feelers. In the earliest stages of development it is destitute of wings, but the fully grown insects are found to possess them. The body is elliptical in shape, and the whole insect a little less than one-third the length the longest diameter of a wheat berry.

The rice weevil is a native of the East Indies, and was imported into the United States by trading vessels from Eastern ports. It is of a black color, and a little less than one-eighth of an inch in length ; the snout is about one-thirty-second of an inch long, or one-fourth the length of the body. The *elytra* are black, with four orange spots.

The female weevil lays a prodigious number of eggs, not in a mass, but one at a time. She first carefully drills a hole in the berry and lays a single egg in the cavity thus formed, the opening of which is plastered up with a glutinous secretion. It requires about fifty days for this egg to develop into a perfect insect. A few days after the egg is laid it hatches into a white grub, which immediately commences devouring the starchy and glutenous portions of the grain surrounding it. After it has eaten all but the woody fibre or covering of the berry, it goes into a second state and becomes a chrysalis, as which it remains about two weeks, when it is metamorphosed into a perfect insect.

As it does not disturb the outer covering, it is very difficult to tell damaged grain. If, however, the suspected grain be put in water, the good

berries will sink, while the shells containing the grub will, from their lightness, float on the surface.

There have been numerous recipes offered for the destruction or prevention of the depredations of weevils, the principal of which are: Kiln drying, sulphur fumes, sprinkling air-slacked lime among the grain. Insect powder, tarred paper, and various other remedies have been suggested. It has been proved that the weevil cannot stand a high degree of heat, and grain heating has been resorted to to kill the eggs and grubs. Weevils cannot live and breed without moisture; if the grain is kept thoroughly clean and dry it is generally safe from the attacks of these pests.

"The *American Agriculturist* says that barn weevils are not brought in the granary in the wheat, but attack the grain only after it is harvested. The granary should have no crevices to harbor or admit the insect, and all ventilation spaces should be covered with fine wire gauze. In France the receptacles are often built of sheet iron."

Pyrethrum roseum, or Persian insect powder, is said to drive away weevils.

"It is said that a bag of hops in each bin will keep grubs or weevils out, or kill them if already in. Aniseed also attracts and kills weevils and prevents their harboring."

"The grain bins, if of wood, should be whitewashed. Weevils hate anything that is clean. One man says that if all else fails put a tarred board in the bin where the weevils are and they will leave on short notice."

"Gum camphor is used, tied in a rag, as a protection against mill bugs."

Rats.—The ravages caused by rats have long been an eyesore and a loss to millers and others. The amount of damage inflicted by them can safely be estimated as amounting to millions of dollars yearly. In the mill, not satisfied with grain destruction, they sometimes attack bolts, screens, sacks, etc., doing in a single night damage requiring days to repair.

Various systematic methods, in the form of traps, poisons, etc., are practised in the hope of increasing the mortality of these pernicious rodents.

Among other methods on record for clearing a building of these pests is one, quite unique in its way, by suffocating them with chlorine gas.

The methods applicable are of a character not allowing free ventilation, as free ventilation allows the gas to escape or mix with so great a quantity of air as to impair its efficiency as a destructive agent.

First plaster up all the holes but one. By pouring greatly moistened chloride of lime down the burrow and following it with diluted muriatic or oxalic acid, chlorine is profusely generated. If now the remaining outlet is closed, the rats are "gone coons."

The same plan can be pursued where rats are between the floors, first nailing up the outlet with sheet iron and proceeding to suffocate in the usual manner. It is said by those who have tried this method that they have been able to free their buildings entirely.

It is stated that premises may be cleared of rats by making lime wash yellow with copperas and covering the stones and rafters in the cellar with it, and also scattering copperas liberally about.

CHAPTER XLI.

MISCELLANEOUS.

Helps to the Miller — Duty — Ordering Machinery — Choice of Stone — Straightening Shafts — Cost and Depreciation of Machinery — Cost of Manufacture — Qualities of Wheat — Cost of Wheat Transportation — Prices of Wheat — Calculations — Problems and Solutions.

Helps to the Miller.—There are plenty of things that many people know, but which they either forget or underrate, hence there is some use in calling their attention to them once in a while. If more men kept note-books than now do, there would be fewer things let go by which ought to be remembered. Very often a miller hears or remembers something which he knows will be of use to him in his business; but he lets it go so long that, when the time comes in which it would be of use to him, it is not at hand. It is a very good plan to keep scrap and note books. The scrap-book and the note-book are great helps to the pocket-book and the bank-book.

Duty.—In the mill let each man have a definite part to perform. If the mill is run on two spells, day and night, let the night miller come in at 5.55 P. M. The day miller, having looked all over the mill, gives the night miller his suggestions or instructions. The night hands should not be allowed to leave the mill while on duty, nor to go to sleep under any consideration. If the miller is allowed to serve as general roustabout, he will, in greater or less degree, lose his fine sense of touch.

Ordering Machinery.—In ordering any kind of special machinery, to do almost any kind of work, it is desirable to have the machines of the best design and make; for, while inferior machines may do work that will pass, or even do good work for a while, there is sooner or later a time when the poor machine gives out, even if it does good work at first; and to merely be able to do work that will sell or that will surpass former achievements, is not enough. It is proper to get the best machine, the best work and the greatest durability. There is more reason for a miller to expect to get good work out of poor rolls, than that they should expect to get work out of burrs of poor stock, badly selected, badly built, badly mounted, badly dressed and run at the wrong speed.

Choice of Stone.—Kick says that for clean, dry, hard wheat, the stone should be close, hard and tough. Pieces of flint prevent the burr from taking a proper dress. For soft wheat of a yellow color, with fine bran, and mealy moist interior, should have a porous stone, tough and sharp. Ordinarily, such wheat grinds tough. The chop or breaks feel soft. The stone must have more pores and be sharp.

Straightening Shafts.—To straighten a wooden shaft, take hard seasoned lumber and dovetail it into the shaft at the crookedest part. To straighten an iron shaft, fix three or five pieces of iron or stone, so that fire will not affect them, and so that their upper surface will be in exact line. Fix the shaft firmly upon them, with the bend up. Build a fire under the shaft and heat it evenly the entire length, when it can be bent down to the straight line of the supports. Do not heat hot enough to cast a scale. Another way is to support the shaft at the ends, let the bend hang down, fasten the ends tightly, and while forcing the bend upward from below with a lever, pene the upper surface with a hammer, so as to stretch or lengthen it. This bent surface must never be turned off, as the shaft would crook again.

Cost and Depreciation of Machinery.—"Best French burrs, 30-inch, cost $175; for every additional inch add $6. This is for stones simply faced; if furrowed add 15 per cent. Curb and feeder, $25, setting $25, depreciation 20 per cent. in twenty-five years. Refilling spur wheels once in six or eight years, $100 to $150. Bolting chests, 16 feet, with 40-inch reel, $360, 20-foot chest $540 (one 12-foot elevator included). Two to four reel chests, including cloths, shafting and gearing, $1,500. Iron bolting reel, $40 to $50. Bolting cloth, $1.25 to $3.50 per yard; making up, 35c. per yard. A forty-inch reel takes one yard of cloth for each foot of reel length. Depreciation of cloth, 25 per cent. to 33 per cent. per year; in an old mill more than this, by reason of bugs. Annual depreciation of the rest of the chest, 3 per cent. Middlings purifiers, $275 for one pair of burrs, $100 additional for every extra pair; average life of a purifier in a merchant mill, eight years. Smutter of ten to fifteen bushels per hour, $110; 125 bushels, $250; life in custom mills, twenty years; in merchant mills, ten years. A smutter can be recased for $15 or $20, and be as good as new. Elevator buckets, 15 to 50 cents each; elevator boot and pulley, $12; rivets, $1.50 per hundred; fastening cups to belts, 2 cents each. The principal wear in elevators is that of the cups. In a merchant mill the leather pulley lasts ten to twelve years, the cups six months to two years. Annual depreciation of slow geared machinery, 5 per cent.; of fast geared, 20 per cent."

Cost of Manufacture.—It is strange how few millers know just how much money it costs to make a barrel of flour; and when it comes to being able to say just how many cents it costs for each item, power, wages, interest, rent, repairs, insurance, etc., there are fewer still who can tell anything about it. We have taken a great deal of trouble and gone to a considerable expense to get from different millers their statements of these items, and while they differ widely, they do not differ any more than the systems of milling. We give, on following page, a statement of cost from an Ohio new process burr mill, running through five years:

The separate accounts will explain themselves in part. It should be added, however, that as the mill is owned by those running it, no direct account of rent is shown. The taxes come under the head of "expense;" current repairs come under that head, but permanent additional value is not shown. The wages cover office services, but nothing charged in the way of

EXPENSE OF MANUFACTURING FLOUR FOR FIVE YEARS, 1875-79 INCLUSIVE, IN AN OHIO MILL.

From July 1 to June 30.	Wheat, Amount Ground.		Expense Account.	Interest and Discount.	Wages.	Insurance.	Repairs.	Aggregate.
	Bushels.	Lbs.						
1875-76	143,997	57	$2,324.66	$4,997.09	$4,384.81	$820.54	$263.83	$12,790.93
1876-77	133,742	29	2,711 14	3,739.52	4,746.93	872.23	586.53	12,656.35
1877-78	83,557	32	2,413.75	2,744.19	4 448.51	718.41	1,188.07	11,512.93
1878-79	117,777	18	1,729.74	2,882.47	4,229.72	709.20	713.93	10,265.06
1879-80	126,628	5	2,605.62	3,046 07	4,269.54	982.91	1,599.65	12,503.79
Aggregate	605,703	21	$11,784.91	$17,409.34	$22,079.51	$4,103.29	$4,352.01	$59,729.06
Average	121,140	40	$2,356 98	$3,481.87	$4,415.90	$820.66	$870.40	$11,945.81

Average cost for manufacturing one bushel of wheat, 9.77 cents, at 4.30-60 per barrel, ... 43.9 cents.

Rents, say 15 cents per barrel, ... 15. "

Say, additional insurance carried by owners, ... 1.1 "

Cost per barrel, ... 60. cents.

partners' wages. Insurance covers as heavy a line as prudence dictates, but it necessarily leaves a risk to be carried by the owners. The mill is driven by water, and maintenance of power is covered in the above.

The Jones single roller machines have not been long used for the entire reduction of wheat to flour, but after making the middlings on millstones they were ground on the single rolls. The cost of manufacture for a run of 11,568 barrels is given by Mr. James Jones, as follows:

Insurance, 1½ cents.; coal, 8⅘ cents; labor, 10⅔ cents, with incidentals only a fraction of a cent. Total for these items, only about 21½ cents. Of course, in these figures, the important items of repair, rent, interest and discount and general expense account are omitted.

Qualities of Wheat.—Millers and grain dealers should impress upon the farmer the importance of improving the quality of his wheat, by taking the best seed each year, so as to get the earliest possible maturity, the largest grass and the best growth.

Black Sea wheat is thin and brittle, and lacks fibre.

Wheat grown in some years is harder and has thicker bran than that of other years.

The Michican winter wheat is about the softest that the miller gets.

In the Pacific wheat there are some things that specially annoy those in charge of the cleaning. California wheat is soft in the northern portion, the Russian River districts, Sonoma and Napa valleys, etc. In the San Joaquin and Clara valleys the wheat is dry and hard; along the coast line it is moist. It is said to gain enough in weight in the passage across the ocean to pay for the freight.

There is a great deal of Oregon wheat that is shipped down to California and passes for California wheat, very much to the disadvantage of the latter, because the Oregon wheat is weak, like Michigan white winter.

For burr mills, or, in fact, for any kind of milling, the red winter Mediterranean is by far preferable. The kinds that are generally the most troublesome in the burrs are Clawson wheat and similar varieties. Yet Clawson seems to do better in New York State, where millers do not find any fault with it.

Good Mediterranean and Russian seed are best for fall planting, give good yields, please the millers and the bakers.

Red wheat is stronger than white; the grain is usually small and hard. The large white grain is peculiarly adapted to making fine white flour.

In practice, 100 pounds of flour make 133 to 136 pounds of bread.

Southern wheat makes more bread than Northern, because, in ripening, there is more evaporation, and the farina being left in a more condensed state will, when made into dough, absorb a larger quantity of water. American wheat is said to absorb 10 to 12 per cent. more water than European. Whereas five bushels of wheat was considered necessary some years ago in the Northern States to make a barrel of flour, now four and a quarter to four

and a half are enough. There is a barrel of excellent superfine flour in 210 pounds of good dried wheat, weighing sixty pounds to the bushel. This shows that there is a loss of nearly a bushel of wheat to each barrel of superfine flour, this loss being mainly from the best and most nutritive part of the grain—the gluten. This is due to imperfect preparation more than to the machinery. It is gluten which determines the real value of wheat flour. The bran of dry wheat is so brittle that it is apt to cut up fine, speck the flour and discolor it. To avoid this, many millers set the stones apart and dress them, so as to partly grind or break open the wheat and get out the white starch of the flour, and then, in an after grinding, the gluten and the bran go in what will be sold as a lower grade of flour on account of its color, though really it contains the most valuable constituents of the grain, and is a more valuable and nourishing flour.

Millers mix soft or dry wheat to a good average, and sprinkle water on the very dry wheat before grinding. Now, dry wheat contains on the inside about 8 per cent. of water, part of which renders it sufficiently tough, if ground at a temperature of 100° Fahrenheit, to be worked easily.

Cost of Wheat Transportation.—In a pamphlet addressed to the "Western Farmers of America," lately issued by the Cobden Club of England, by Augustus Mongredier, we are assured that we are paying a grievous tax in the way of railway transportation of our crops, in consequence of the heavy cost of rails used in the construction of our roads. To show the absurdity of this assumption it is only necessary to look at the price of freight on wheat from Chicago to New York for a series of years.

At the close of the war the price of transporting a bushel of wheat between the above points was sixty-four cents. The reduction from that to fifteen cents, the present price, is shown by the following figures from the report of the United States Bureau of Statistics, for 1879, to bear no relation to the fluctuation in the price of railroad iron.

1873,	average	per	bushel,	32	cents.
1874,	"	"		28	"
1875,	"	"		24	"
1876,	"	"		16	"
1877,	"	"		20	"
1878,	"	"		17	"

It is doubtful if grain can be carried on English railroads with their low-priced rails or cheap labor. The strong competition between the several railroad lines, and between these and lake transportation, gives the grain producers of the west very low through rates. But it is hard to please our English neighbors while we make our own railroad iron instead of buying Welsh rails.

Underneath the reader will find a tabulated summary of the average shipping freights which have been paid on wheat and corn during the ten

years ended 1880, from Chicago to Buffalo, and from Buffalo (by way of the Erie canal) to New York:

Year.	Lake.		Canal.	
	Wheat.	Corn.	Wheat.	Corn.
1870	5.0c.	4.7c.	9.4c.	9.2c.
1871	6.2	5.7	11.8	10.8
1872	9.6	8.8	12.0	10.0
1873	6.5	5.6	10.06	9.6
1874	3.1	2.0	9.0	8.0
1875	2.8	2.6	7.5	6.9
1876	1.6	1.1	5.9	5.4
1877	2.6	2.2	5.4	4.7
1878	1.7	1.5	4.3	3.8
1879	2.5	2.3	5.2	4.7
1880	4.8	4.3	6.0	5.1

Calculations.—A two-foot rule was given to a laborer in a Clyde boat-yard to measure an iron plate. The lumper, not being well up to the use of the rule, after spending a considerable time returned. "Noo, Mick," asked the plater, "what size is the plate?" "Well," replied Mick, with a grin of satisfaction, "it's the length of your rule, and two thumbs over, with this piece of brick and the breadth of my hand, and my arm from here to there, bar a finger."

To find the capacity of a hopper, multiply the length by the breadth, and this product by one-third of the depth, measuring to the point (in inches), and divide the last product by 2,150, the number of cubic inches in a bushel.

The length of belting in coils may be found by taking half the sum of the diameters of the inner and outer coils, multiplying the number by 3.1416 and the product by the number of coils. If the diameter of the coils be taken in inches, this will give the length of the coil in inches.

For diameter in centimetres to circumference in metres, diameter multiplied by .0314.

For circumference of a circle, diameter multiplied by 3.1416.

For getting circumference in feet from diameter in inches, diameter in inches multiplied by $\frac{3.1416}{12} = .2633$.

To get circumference in feet from diameter in centimetres, multiply the diameter in centimetres by $\frac{3.1416 \times .3937}{12} = 103$.

Prices of Wheat.—As a ready reference for the purpose of calculating the price of wheat, the tables on the succeeding pages will be found very useful.

Calculations as to Prices of Wheat.

Pounds.	Bushels.	76.		Bushels.	80.		Bushels.	85.	
		Dolls.	Cents.		Dolls.	Cents.		Dolls.	Cents.
60	1		.76	1		.80	1		.85
120	2	1	.52	2	1	.60	2	1	.70
180	3	2	.28	3	2	.40	3	2	.55
240	4	3	.04	4	3	.20	4	3	.40
300	5	3	.80	5	4	.00	5	4	.25
360	6	4	.56	6	4	.80	6	5	.10
420	7	5	.32	7	5	.60	7	5	.95
480	8	6	.08	8	6	.40	8	6	.80
540	9	6	.84	9	7	.20	9	7	.65
600	10	7	.60	10	8	.00	10	8	.50
660	11	8	.36	11	8	.80	11	9	.35
720	12	9	.12	12	9	.60	12	10	.20
780	13	9	.88	13	10	.40	13	11	.05
840	14	10	.64	14	11	.20	14	11	.90
900	15	11	.40	15	12	.00	15	12	.75
960	16	12	.16	16	12	.80	16	13	.60
1020	17	12	.92	17	13	.60	17	14	.45
1080	18	13	.68	18	14	.40	18	15	.30
1140	19	14	.44	19	15	.20	19	16	.15
1200	20	15	.20	20	16	.00	20	17	.00
1260	21	15	.96	21	16	.80	21	17	.85
1320	22	16	.72	22	17	.60	22	18	.70
1380	23	17	.48	23	18	.40	23	19	.55
1440	24	18	.24	24	19	.20	24	20	.40
1500	25	19	.00	25	20	.00	25	21	.25
1560	26	19	.76	26	20	.80	26	22	.10
1620	27	20	.52	27	21	.60	27	22	.95
1680	28	21	.28	28	22	.40	28	23	.80
1740	29	22	.04	29	23	.20	29	24	.65
1800	30	22	.80	30	24	.00	30	25	.50
1860	31	23	.56	31	24	.80	31	26	.35
1920	32	24	.32	32	25	.60	32	27	.20
1980	33	25	.08	33	26	.40	33	28	.05
2040	34	25	.84	34	27	.20	34	28	.90
2100	35	26	.60	35	28	.00	35	29	.75
2160	36	27	.36	36	28	.80	36	30	.60
2220	37	28	.12	37	29	.60	37	31	.45
2280	38	28	.88	38	30	.40	38	32	.30
2340	39	29	.64	39	31	.20	39	33	.15
2400	40	30	.40	40	32	.00	40	34	.00
2460	41	31	.16	41	32	.80	41	34	.85
2520	42	31	.92	42	33	.60	42	35	.70
2580	43	32	.68	43	34	.40	43	36	.55
2640	44	33	.44	44	35	.20	44	37	.40
2700	45	34	.20	45	36	.00	45	38	.25
2760	46	34	.96	46	36	.80	46	39	.10
2820	47	35	.72	47	37	.60	47	39	.95
2880	48	36	.48	48	38	.40	48	40	.80
2940	49	37	.24	49	39	.20	49	41	.65
3000	50	38	.00	50	40	.00	50	42	.50

CALCULATIONS AS TO PRICES OF WHEAT.—CONTINUED.

Pounds.	Bushels.	90.		Bushels.	95.		Bushels.	1.00.	
		Dolls.	Cents.		Dolls.	Cents.		Dolls.	Cents.
60	1		.90	1		.95	1	1	.00
120	2	1	.80	2	1	.90	2	2	.00
180	3	2	.70	3	2	.85	3	3	.00
240	4	3	.60	4	3	.80	4	4	.00
300	5	4	.50	5	4	.75	5	5	.00
360	6	5	.40	6	5	.70	6	6	.00
420	7	6	.30	7	6	.65	7	7	.00
480	8	7	.20	8	7	.60	8	8	.00
540	9	8	.10	9	8	.55	9	9	.00
600	10	9	.00	10	9	.50	10	10	.00
660	11	9	.90	11	10	.45	11	11	.00
720	12	10	.80	12	11	.40	12	12	.00
780	13	11	.70	13	12	.35	13	13	.00
840	14	12	.60	14	13	.30	14	14	.00
900	15	13	.50	15	14	.25	15	15	.00
960	16	14	.40	16	15	.20	16	16	.00
1020	17	15	.30	17	16	.15	17	17	.00
1080	18	16	.20	18	17	.10	18	18	.00
1140	19	17	.10	19	18	.05	19	19	.00
1200	20	18	.00	20	19	.00	20	20	.00
1260	21	18	.90	21	19	.95	21	21	.00
1320	22	19	.80	22	20	.90	22	22	.00
1380	23	20	.70	23	21	.85	23	23	.00
1440	24	21	.60	24	22	.80	24	24	.00
1500	25	22	.50	25	23	.75	25	25	.00
1560	26	23	.40	26	24	.70	26	26	.00
1620	27	24	.30	27	25	.65	27	27	.00
1680	28	25	.20	28	26	.60	28	28	.00
1740	29	26	.10	29	27	.55	29	29	.00
1800	30	27	.00	30	28	.50	30	30	.00
1860	31	27	.90	31	29	.45	31	31	.00
1920	32	28	.80	32	30	.40	32	32	.00
1980	33	29	.70	33	31	.35	33	33	.00
2040	34	30	.60	34	32	.30	34	34	.00
2100	35	31	.50	35	33	.25	35	35	.00
2160	36	32	.40	36	34	.20	36	36	.00
2220	37	33	.30	37	35	.15	37	37	.00
2280	38	34	.20	38	36	.10	38	38	.00
2340	39	35	.10	39	37	.05	39	39	.00
2400	40	36	.00	40	38	.00	40	40	.00
2460	41	36	.90	41	38	.95	41	41	.00
2520	42	37	.80	42	39	.90	42	42	.00
2580	43	38	.70	43	40	.85	43	43	.00
2640	44	39	.60	44	41	.80	44	44	.00
2700	45	40	.50	45	42	.75	45	45	.00
2760	46	41	.40	46	43	.70	46	46	.00
2820	47	42	.30	47	44	.65	47	47	.00
2880	48	43	.20	48	45	.60	48	48	.00
2940	49	44	.10	49	46	.55	49	49	.00
3000	50	45	.00	50	47	.50	50	50	.00

CALCULATIONS AS TO PRICES OF WHEAT.—CONTINUED.

Pounds.	Bushels.	1.05.		Bushels.	1.10.		Bushels.	1.15.	
		Dolls.	Cents.		Dolls.	Cents.		Dolls.	Cents.
60	1	1.05		1	1.10		1	1.15	
120	2	2.10		2	2.20		2	2.30	
180	3	3.15		3	3.30		3	3.45	
240	4	4	20	4	4.40		4	4.60	
300	5	5.25		5	5.50		5	5.75	
360	6	6.30		6	6.60		6	6.90	
420	7	7.35		7	7.70		7	8.05	
480	8	8.40		8	8.80		8	9.20	
540	9	9.45		9	9.90		9	10.35	
600	10	10.50		10	11.00		10	11.50	
660	11	11.55		11	12.10		11	12.65	
720	12	12.60		12	13.20		12	13.80	
780	13	13.65		13	14.30		13	14.95	
840	14	14.70		14	15.40		14	16.10	
900	15	15.75		15	16.50		15	17.25	
960	16	16.80		16	17.60		16	18.40	
1020	17	17.85		17	18.70		17	19.55	
1080	18	18.90		18	19.80		18	20.70	
1140	19	19.95		19	20.90		19	21.85	
1200	20	21.00		20	22.00		20	23.00	
1260	21	22.05		21	23.10		21	24.15	
1320	22	23.10		22	24.20		22	25.30	
1380	23	24.15		23	25.30		23	26.45	
1440	24	25.20		24	26.40		24	27.60	
1500	25	26.25		25	27.50		25	28.75	
1560	26	27.30		26	28.60		26	29.90	
1620	27	28.35		27	29.70		27	31.05	
1680	28	29.40		28	30.80		28	32.20	
1740	29	30.45		29	31.90		29	33.35	
1800	30	31.50		30	33.00		30	34.50	
1860	31	32.55		31	34.10		31	35.65	
1920	32	33.60		32	35.20		32	36.80	
1980	33	34.65		33	36.30		33	37.95	
2040	34	35.70		34	37.40		34	39.10	
2100	35	36.75		35	38.50		35	40.25	
2160	36	37.80		36	39.60		36	41.40	
2220	37	38.85		37	40.70		37	42.55	
2280	38	39.90		38	41.80		38	43.70	
2340	39	40.95		39	42.90		39	44.85	
2400	40	42.00		40	44.00		40	46.00	
2460	41	43.05		41	45.10		41	47.15	
2520	42	44.10		42	46.20		42	48.30	
2580	43	45.15		43	47.30		43	49.45	
2640	44	46.20		44	48.40		44	50.60	
2700	45	47.25		45	49.50		45	51.75	
2760	46	48.30		46	50.60		46	52.90	
2820	47	49.35		47	51.70		47	54.05	
2880	48	50.40		48	52.80		48	55.20	
2940	49	51.45		49	53.90		49	56.35	
3000	50	52.50		50	55.00		50	57.50	

CALCULATIONS AS TO PRICES OF WHEAT.—CONTINUED.

Pounds.	Bushels.	1.20.		Bushels.	1.25.		Bushels.	1.30.	
		Dolls.	Cents.		Dolls.	Cents.		Dolls.	Cents.
60	1	1.20		1	1.25		1	1.30	
120	2	2.40		2	2.50		2	2.60	
180	3	3.60		3	3.75		3	3.90	
240	4	4.80		4	5.00		4	5.20	
300	5	6.00		5	6.25		5	6.50	
360	6	7.20		6	7.50		6	7.80	
420	7	8.40		7	8.75		7	9.10	
480	8	9.60		8	10.00		8	10.40	
540	9	10.80		9	11.25		9	11.70	
600	10	12.00		10	12.50		10	13.00	
660	11	13.20		11	13.75		11	14.30	
720	12	14.40		12	15.00		12	15.60	
780	13	15.60		13	16.25		13	16.90	
840	14	16.80		14	17.50		14	18.20	
900	15	18.00		15	18.75		15	19.50	
960	16	19.20		16	20.00		16	20.80	
1020	17	20.40		17	21.25		17	22.10	
1080	18	21.60		18	22.50		18	23.40	
1140	19	22.80		19	23.75		19	24.70	
1200	20	24.00		20	25.00		20	26.00	
1260	21	25.20		21	26.25		21	27.30	
1320	22	26.40		22	27.50		22	28.60	
1380	23	27.60		23	28.75		23	29.90	
1440	24	28.80		24	30.00		24	31.20	
1500	25	30.00		25	31.25		25	32.50	
1560	26	31.20		26	32.50		26	33.80	
1620	27	32.40		27	33.75		27	35.10	
1680	28	33.60		28	35.00		28	36.40	
1740	29	34.80		29	36.25		29	37.70	
1800	30	36.00		30	37.50		30	39.00	
1860	31	37.20		31	38.75		31	40.30	
1920	32	38.40		32	40.00		32	41.60	
1980	33	39.60		33	41.25		33	42.90	
2040	34	40.80		34	42.50		34	44.20	
2100	35	42.00		35	43.75		35	45.50	
2160	36	43.20		36	45.00		36	46.80	
2220	37	44.40		37	46.25		37	48.10	
2280	38	45.60		38	47.50		38	49.40	
2340	39	46.80		39	48.75		39	50.70	
2400	40	48.00		40	50.00		40	52.00	
2460	41	49.20		41	51.25		41	53.30	
2520	42	50.40		42	52.50		42	54.60	
2580	43	51.60		43	53.75		43	55.90	
2640	44	52.80		44	55.00		44	57.20	
2700	45	54.00		45	56.25		45	58.50	
2760	46	55.20		46	57.50		46	59.80	
2820	47	56.40		47	58.75		47	61.10	
2880	48	57.60		48	60.00		48	62.40	
2940	49	58.80		49	61.25		49	63.70	
3000	50	60.00		50	62.50		50	65.00	

Problems and Solutions.—PROBLEM 1.—To find the circumference of a circle or a pulley :

Solution.—Multiply the diameter by 3.1416 ; or (approximately) as 7 is to 22 so is the diameter to the circumference.

PROBLEM 2.—To compute the diameter of a circle or a pulley :

Solution.—Divide the circumference by 3.1416, or multiply the circumference by .3183, or (approximately) as 22 is to 7 so is the circumference to the diameter.

PROBLEM 3.—To compute the area of a circle :

Solution.—Multiply the circumference by one quarter of the diameter, or multiply the square of the diameter by .7854 ; or multiply the square of the circumference by .07958 ; or multiply half the circumference by half the diameter; or multiply the square of half the diameter by 3.1416.

PROBLEM 4.—To find the surface of a sphere or globe :

Solution.—Multiply the diameter by the circumference ; or multiply the square of the diameter by 3.1416 ; or multiply four times the square of the radius by 3.1416.

PROBLEM 5.—To compute the diameter of the pitch circle of a toothed wheel :

Solution.—Multiply the circular pitch in inches by the number of teeth, and divide by 3.1416. To get the radius of pitch circle, divide circumference by 6.2832.

PROBLEM 6.—To compute the number of teeth in follower to have any given velocity.

Solution.—Multiply the velocity or number of revolutions of the driver by its number of teeth or its diameter, and divide the product by the desired number of revolutions of the follower.

PROBLEM 7.—To compute the diameter of a follower, when the diameter of the driver and the number of teeth in driver and follower are given :

Solution.—Multiply the diameter of driver by the number of teeth in the driven, and divide the product by the number of teeth in the driver, and the quotient will be the diameter of follower.

PROBLEM 8.—To compute the number of revolutions of a follower, when the number of revolutions of driver and the diameter or the number of teeth or driven are given :

Solution.—Multiply the number of revolutions of driver by its number of teeth or its diameter, and divide the product by the number of teeth or the diameter of the driven.

PROBLEM 9.—To ascertain the number of revolutions of a driver, when the revolutions of driven and teeth or diameter of driver and driven are given :

Solution.—Multiply the number of teeth or the diameter of driven by its revolutions and divide the product by the number of teeth or the diameter of driver.

PROBLEM 10.—To ascertain the number of revolutions of the last wheel at the end of a train of spur wheels, all of which are in a line and mesh into one another, when the revolutions of the first wheel and the number of teeth or the diameter of the first and last are given :

Solution.—Multiply the revolutions of first wheel by its number of teeth or its diameter and divide the product by the number of teeth or the diameter of the last wheel ; the result is its number of revolutions.

PROBLEM 11.—To ascertain the number of teeth in each wheel for a train of spur wheels, each to have a given velocity :

Solution.—Multiply the number of revolutions of the driving wheel by its number of teeth, and divide the product by the number of revolutions each wheel is to make, to ascertain the number of teeth required for each.

PROBLEM 12.—To compute the number of revolutions of the last wheel in a train of wheels and pinions, spurs or bevels, when the revolutions of the first or driver, and the diameter, the teeth or the circumference of all the drivers and pinions are given :

Solution.—Multiply the diameter, the circumference or number of teeth of all the driving wheels together, and this continued product by the number of revolutions of the first wheel, and divide this product by the continued product of the diameter, the circumference or the number of teeth of all the pinions, and the quotient will be the number of revolutions of the last wheel. Example : If the diameters, the circumferences or the number of teeth of a train of wheels are 8, 8, 10, 12 and 6, and the diameters, circumferences or number of teeth of the pinions are 4, 5, 5, 5 and 6, and the driver have ten revolutions, what will be the number of revolutions for the last pinion? Multiply all the drivers together and then by ten revolutions, and you have 8 by 8 by 10 by 12 by 6 by 10 equal to 460800 ; divide this amount by the product of the figures for pinions 4 by 5 by 5 by 5 by 6 = 3000, and the quotient will be 153, or the number of revolutions of last wheel. This rule is equally applicable to a train of pulleys, the given elements being the diameter and the circumference.

PROBLEM 13.—To find the number of revolutions of driven pulley, the revolutions of driver and diameter of driver and driven being given :

Solution.—Multiply the revolutions of driver by its diameter and divide the product by the diameter of driven.

PROBLEM 14.—To compute the diameter of driven pulley for any desired number of revolutions, the size and velocity of driver being known :

Solution.—Multiply the velocity of driver by its diameter and divide the product by the number of revolutions it is desired the driven shall make.

PROBLEM 15.—To ascertain the diameter of driving pulley :

Solution.—Multiply the diameter of driven by the number of revolutions you desire it shall make, and divide the product by the number of revolutions of the driver.

PROBLEM 16.—To find the velocity or number of revolutions of the last wheel to one of the first.

Rule: Divide the product of the number of teeth of the wheels that act as driver by the product of the number of teeth in the driven.

Example: If a wheel of 32 teeth drive a pinion of 10, on the axis of which there is one of 30 teeth, acting on a pinion of 8, what is the number of turns of the last?

$$\frac{32}{10} \times \frac{30}{8} \quad \frac{960}{8} = 12. \quad \text{Answer.}$$

Other problems and calculations are found throughout the text, and may be found by consulting the Index.

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